BYTE

July–September 1987

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WELCOME TO BYTE'S QUARTERLY LISTINGS SUPPLEMENT

The BYTE Listings Supplement is produced quarterly as a means of providing interested readers with a printed, source code version of those programs referenced in BYTE articles. It provides a far more extensive look into the techniques of coding and the potentialities of microcomputers than we have space for in each month's BYTE.

Programs contained in this Supplement are referenced by the month the article appeared, the page on which their supporting article begins, and the name of the author who wrote the article.

For those who prefer programs already in electronic format, we have a companion service called Listings on Disk. If you have a modem, listings may be downloaded from the BYTEnet bulletin board and, if you are a member of BIX, the "Listings" area also contains programs referenced in BYTE.

If you live outside of the U.S., we've included the names, addresses and telephone numbers of bulletin boards that get program code from us. You'll find the directory just inside the back cover of this Supplement.

The bulletin boards are updated monthly. Several countries have enough boards that the telephone charges for most callers should be the minimum possible.

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July

BENCH.ADA Contributed by Namir Clement Shammas.
Listings accompany the review of four Ada compilers: Alsys Ada, Artek Ada, AdaVantage, and JANUS Ada, "Ada Moves to Micros," July 1987, page 239.

Listing 1: Source code for Ada Sieve benchmark program.

```
with TEXT_IO;
use TEXT_IO;

-- package INTIO is new INTEGER_IO(INTEGER);

PROCEDURE MTSIE10 is

SIZE : constant INTEGER := 7000;

TYPE Flag_Array is array(0..SIZE) of BOOLEAN;

PRIME, K, COUNT : INTEGER;
FLAGS : Flag_Array;

BEGIN

  PUT_LINE("START TEN ITERATIONS");
  FOR ITER IN 1..10 LOOP
    COUNT := 0;

    FOR I IN 0..SIZE LOOP
      FLAGS(I) := TRUE;
    END LOOP;

    FOR I IN 0..SIZE LOOP

      IF FLAGS(I) THEN
        PRIME := I + I + 3;
        K := I + PRIME;

        WHILE K <= SIZE LOOP
          FLAGS(K) := FALSE;
          K := K + PRIME;
        END LOOP;

        COUNT := COUNT + 1;

      END IF;

    END LOOP;

 END LOOP;

  PUT(INTEGER'IMAGE(COUNT));
  PUT_LINE(" PRIMES");

END MTSIE10;
```

Listing 2: Source code for Ada integer Sort benchmark program.

```
with TEXT_IO;
use TEXT_IO;

Procedure MTSort2 is
-- Program will test the speed of sorting an integer array.
-- The program will create an array sorted from smaller to larger
-- integers, then sort them in the reverse order.
-- The array is reverse-sorted ten times.
```

continued

```
 package INTIO is new INTEGER_IO(INTEGER);

SIZE : constant := 1000;

TYPE NUMBERS is ARRAY(1..SIZE) OF INTEGER;

InOrder, AscendingOrder : BOOLEAN;
Offset, Temporary : INTEGER;
Ch : CHARACTER;
A : NUMBERS;

PROCEDURE InitializeArray is
-- Procedure to initialize array
BEGIN
  PUT_LINE("Initializing integer array");
  FOR I IN 1..SIZE LOOP
    A(I) := I;
  END LOOP;
END InitializeArray;

PROCEDURE ShellSort is
-- Procedure to perform a Shell-Metzner sorting

I : INTEGER;

  PROCEDURE SwapThem(I, J : in INTEGER) is
  -- Local procedure to swap elements A(I) and A(J)
  BEGIN
   InOrder := FALSE;
   Temporary := A(I);
   A(I) := A(J);
   A(J) := Temporary;
  END SwapThem;

  BEGIN
   -- Toggle "AscendingOrder" flag status
     AscendingOrder := NOT AscendingOrder;
     Offset := SIZE;
     WHILE Offset > 1 LOOP
       Offset := Offset/2;
       LOOP
         InOrder := TRUE;
         FOR J IN 1..(SIZE - Offset) LOOP
           I := J + Offset;
           IF AscendingOrder
             THEN IF A(I) < A(J) THEN SwapThem(I,J); END IF;
             ELSE IF A(I) > A(J) THEN SwapThem(I,J); END IF;
           END IF; -- AscendingOrder
         END LOOP;
         IF InOrder THEN EXIT; END IF;
       END LOOP;
     END LOOP;
 END ShellSort;

 PROCEDURE DisplayArray is
 -- Display array members
 BEGIN
   FOR I IN 1..SIZE LOOP
     INTIO.PUT(A(I),3);
     PUT(" ");
   END LOOP;
   NEW_LINE;
 END DisplayArray;

 BEGIN -- Main
   InitializeArray;
   AscendingOrder := TRUE;
   PUT("Beginning to sort press <cr> "); GET(Ch); NEW_LINE;
   FOR Iter IN 1..10 LOOP
    PUT(".");
    ShellSort;
   END LOOP;
   PUT_LINE("Finished sorting!");
   DisplayArray;
 END MTSort2;
```

Listing 3: Source code for Ada basic Floating benchmark program.

```
WITH TEXT_IO; USE TEXT_IO;
PROCEDURE MTFLOAT is

PACKAGE RealInOut is new FLOAT_IO(FLOAT);
USE RealInOut;

NR : CONSTANT INTEGER := 5000;

A, B, C : FLOAT;

BEGIN
  A := 2.71828;
  B := 3.1459;
  C := 1.0;

  FOR I IN 1..NR LOOP
    C := C * A;
    C := C * B;
    C := C / A;
    C := C / B;
  END LOOP;

  PUT("DONE");
  NEW_LINE;
  PUT("ERROR = ");
  PUT((C-1.0));
  NEW_LINE;
END MTFLOAT;
```

Listing 4: Source code for Ada matrix-inversion Floating benchmark program.

```
with TEXT_IO;
use TEXT_IO;

Procedure MTINVERT is

-- Program to test speed of floating-point matrix inversion.
-- The program will form a matrix with 1s in every member,
-- except the diagonals which will have values of 2.

 package RealInOut is new FLOAT_IO(FLOAT);

 MAX : constant := 20;

 TYPE MATRIX is ARRAY (1..MAX,1..MAX) OF FLOAT;

 J, K, L: INTEGER;
 DET, PIVOT, TEMPO: FLOAT;
 A: MATRIX;

Procedure Invert is

  BEGIN

-- Creating test matrix

 FOR J IN 1..MAX LOOP

  FOR K IN 1..MAX LOOP

   A(J, K) := 1.0;

  END LOOP;

  A(J, J) := 2.0;

 END LOOP;


 PUT_LINE("Starting matrix invertion");


 DET := 1.0;
```

continued

```
  FOR J IN 1..MAX LOOP

   PIVOT := A(J, J);
   DET := DET*PIVOT;
   A(J, J) := 1.0;

   FOR K IN 1..MAX LOOP

    A(J, K) := A(J, K) / PIVOT;

   END LOOP;

   FOR K IN 1..MAX LOOP

     IF K /= J THEN

      TEMPO := A(K, J);
      A(K, J) := 0.0;

      FOR L IN 1..MAX LOOP

       A(K, L) := A(K, L) - A(J, L) * TEMPO;

      END LOOP;

     END IF;

    END LOOP;

  END LOOP;

END Invert;

BEGIN

  NEW_LINE(2);
  Invert;
  PUT("Determinant = ");
  RealInOut.PUT(DET,14,10);
  NEW_LINE(2);

END MTINVERT;
```

Listing 5: Source code for Ada Math Functions benchmark program.

```
-- use Janus/Ada libraries
WITH TEXT_IO; WITH SMATHLIB;
USE TEXT_IO; USE SMATHLIB;

PROCEDURE MTMath is

-- Program tests the speed of math function.
-- Each function is timed separately.
-- Functions are shown in the import list.


pi, angle, result, argument: FLOAT;
dummy: CHARACTER;

BEGIN
 PUT_LINE("START SQUARE ROOT TEST");
 PUT("PRESS <CR> TO START");
 GET(dummy); New_Line;

 FOR i in 1..10 LOOP
  PUT(".");
  argument := 0.0;
  WHILE argument <= 1000.0 LOOP
   result := Sqrt(argument);
   argument := argument + 1.0;
  END LOOP;
 END LOOP;

 New_Line; PUT("END OF SQUARE ROOT TEST"); New_Line;
```

```
 PUT("START LOG TEST");
 New_Line;
 PUT("PRESS <CR> TO START");
 GET(dummy); New_Line;

 FOR i in 1..10 LOOP
  PUT(".");
  argument := 0.1;
  WHILE argument <= 1000.1 LOOP
   result := Log(argument);
   argument := argument + 1.0;
  END LOOP;
 END LOOP;

 New_Line; PUT("END OF LOG TEST"); New_Line;

 PUT("START EXPONENTIAL TEST");
 New_Line;
 PUT("PRESS <CR> TO START");
 GET(dummy); New_Line;

 FOR i in 1..10 LOOP
  PUT(".");
  argument := 0.1;
  WHILE argument <= 10.0 LOOP
   result := exp(argument);
   argument := argument + 0.01;
  END LOOP;
 END LOOP;

 New_Line; PUT("END OF EXPONENTIAL TEST"); New_Line;

 PUT("START ARCTANGENT TEST");
 New_Line;
 PUT("PRESS <CR> TO START");
 GET(dummy); New_Line;

 FOR i in 1..10 LOOP
  PUT(".");
  argument := 0.1;
  WHILE argument <= 10.0 LOOP
   angle := arctan(argument);
   argument := argument + 0.01;
  END LOOP;
 END LOOP;

 New_Line; PUT("END OF ARCTANGENT TEST"); New_Line;


 pi := 355.0/113.0;
 PUT("START SINE TEST");
 New_Line;
 PUT("PRESS <CR> TO START");
 GET(dummy); New_Line;

 FOR i in 1..10 LOOP
  PUT(".");
  angle := 0.0;
  WHILE angle <= 2.0 * pi LOOP
   result := sin(angle);
   angle := angle + pi/360.0;
  END LOOP;
 END LOOP;

 New_Line; PUT("END OF SINE TEST"); New_Line;
 New_Line;
 PUT("DONE"); New_Line; New_Line;

END MTMath;
```

Listing 6: Source code for Ada Recursion benchmark program.

```
with TEXT_IO;
use TEXT_IO;

Procedure MTQSort is
```

continued

```
-- The test uses QuickSort to measure recursion speed.
-- An ordered array is created by the program and is
-- reverse-sorted. The process is performed "MAXITER"
-- number of times.

package Int_IO is new INTEGER_IO(INTEGER);

SIZE : constant := 1000;
MAXITER : constant := 10;
WantToListArray : constant BOOLEAN := FALSE; -- Flag used for debugging

TYPE Numbers is ARRAY(1..SIZE) OF INTEGER;

A : Numbers;

PROCEDURE InitializeArray is
-- Procedure to initialize array

BEGIN
  FOR I in 1..SIZE LOOP
    A(I) := SIZE - I + 1;
  END LOOP;
  NEW_LINE(3);
END InitializeArray;

PROCEDURE QuickSort is
-- Procedure to perform a QuickSort

PROCEDURE Sort(Left, Right : INTEGER) is

i, j : INTEGER;
Data1, Data2 : INTEGER;

BEGIN
  i := Left; j := Right;
  Data1 := A((Left + Right) / 2);
  LOOP
    WHILE A(i) < Data1 LOOP i := i + 1; END LOOP;
    WHILE Data1 < A(j) LOOP j := j - 1; END LOOP;
    IF i <= j THEN
      Data2 := A(i); A(i) := A(j); A(j) := Data2;
      i := i + 1;
      j := j - 1;
    END IF;
    IF i > j THEN EXIT; END IF;
  END LOOP;
  IF Left < j THEN Sort(Left,j); END IF;
  IF i < Right THEN Sort(i,Right); END IF;
END Sort;

BEGIN
  Sort(1,SIZE);
END QuickSort;

PROCEDURE DisplayArray is
-- Display array members
BEGIN
  FOR I in 1..SIZE LOOP
    Int_IO.PUT(A(I),4);
    PUT(" ");
  END LOOP;
  NEW_LINE;
END DisplayArray;

BEGIN -- Main
  FOR Iter in 1..MAXITER LOOP
   InitializeArray;
   PUT(".");
   QuickSort;
  END LOOP;
  NEW_LINE;
  PUT_LINE("Finished sorting!");
  IF WantToListArray THEN DisplayArray; END IF;
END MTQSort;
```

Listing 7: Source code for Ada Dynamic Allocation benchmark program.

```
with TEXT_IO;
use TEXT_IO;

PROCEDURE MTPtr is

-- Program to measure the speed of:
-- 1) Allocating dynamic binary-tree structure
-- 2) Searching through the binary tree


SIZE : constant INTEGER := 1000;
MainLoopCount : constant INTEGER := 200;

TYPE Node;

TYPE Ptr is access Node;

TYPE Node is record
        Value : INTEGER;
        Left, Right : Ptr;
       end record;

TYPE NumbersArray is ARRAY (1..SIZE) OF INTEGER;

Numbers : NumbersArray;
TreeRoot : Ptr;
dummy : CHARACTER;


PROCEDURE Create is

J : INTEGER := 1;

BEGIN

  WHILE J <= SIZE LOOP
    IF (J >= 1) AND (J < 251) THEN
     Numbers(J) := J;
    ELSIF (J > 250) AND (J < 501) THEN
     Numbers(J) := SIZE - J;
    ELSIF (J > 500) AND (J < 750) THEN
     Numbers(J) := J;
    ELSE
     Numbers(J) := SIZE - J;
    END IF;
    J := J + 1;
    PUT(INTEGER'IMAGE(J) & " ");
  END LOOP;
  new_line;
END Create;

PROCEDURE Insert(Root : in out Ptr; Item : INTEGER) is
-- Insert element in binary tree
BEGIN
  IF Root = null THEN
    Root := new Node;
    Root.Value := Item;
    Root.Left := null;
    Root.Right := null;
  ELSE
    IF Item < Root.Value THEN Insert(Root.Left,Item);
                         ELSE Insert(Root.Right,Item);
    END IF;
  END IF;
END Insert;


PROCEDURE Search(Root : in out Ptr; Target : INTEGER) is
-- Recursive procedure to search for Target value
```

continued

```
BEGIN
  IF not (Root = null) THEN
    IF not (Target = Root.Value) THEN
      IF Target < Root.Value THEN
        Root := Root.Left; Search(Root,Target);
      ELSE
        Root := Root.Right;
        Search(Root,Target);
      END IF;
    END IF;
  END IF;
END Search;

BEGIN -- MAIN
  Create;
  PUT_LINE("Created array");
  -- Building the binary tree
  PUT("Press <CR> to time tree creation ");
  GET(dummy); NEW_LINE;
  TreeRoot := null;
  FOR I IN 1..SIZE LOOP
   Insert(TreeRoot,Numbers(I));
  END LOOP;
  NEW_LINE;
  PUT_LINE("Created Tree");
  PUT("Press <CR> to time tree search ");
  GET(dummy); NEW_LINE;
  FOR Iter IN 1..MainLoopCount LOOP
    FOR I IN reverse 1..SIZE LOOP
      Search(TreeRoot,Numbers(I));
    END LOOP;
  END LOOP;
  NEW_LINE;
  PUT_LINE("DONE");
END MTPtr;
```

Listing 8: Source code for Ada Disk Write benchmark program.

```
with TEXT_IO;
use TEXT_IO;

Procedure MTWRITE is

Num_Rec : constant := 512;

Small : STRING(1..30);
Big : STRING(1..120);
F : FILE_TYPE;

BEGIN
 Small(1..30) := "123456781234567812345678123456";
 Big := Small & Small & Small & Small;

 CREATE(F, OUT_FILE, "A:TEMPO.DAT");

 FOR I in 1..Num_Rec LOOP
   PUT_LINE(F, Big);
 END LOOP;

 CLOSE(F);
 PUT_LINE("DONE");

END MTWRITE;
```

Listing 9: Source code for Ada Disk Read benchmark program.

```
with TEXT_IO;
use TEXT_IO;

Procedure MTREAD is

Num_Rec : constant := 512;

Big : STRING(1..120);
Last : NATURAL;
F : FILE_TYPE;
```

```
BEGIN

 OPEN(F, IN_FILE, "A:TEMPO.DAT");

 FOR I in 1..Num_Rec LOOP
   GET_LINE(F, Big, Last);
 END LOOP;
 CLOSE(F);
 PUT_LINE("DONE");
END MTREAD;
```

DHRY.C Dhrystone benchmark program by Reinhold P. Weicker, translated from Ada by Rick Richardson.
Listing accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
*          EVERBODY:          Please read "APOLOGY" below. -rick 01/06/85
*                             See introduction in net.arch, or net.micro
*
*          "DHRYSTONE" Benchmark Program
*
*          Version:           C/1.1, 12/01/84
*
*          Date:              PROGRAM updated 01/06/86, RESULTS updated 03/31/86
*
*          Author:            Reinhold P. Weicker, CACM vol. 27, no. 10, 10/84, pg. 1013
*                             Translated from Ada by Rick Richardson
*                             Every method to preserve Ada likeness has been used, at the expense of C-ness.
*
*          Compile:           cc -O dry.c -o drynr                    : No registers
*                             cc -O -DREG=register dry.c -o dryr      : Registers
*
*          Defines:           Defines are provided for old C compilers that don't have enums and can't assign structures.
*                             The time(2) function is library-dependent; most return the time in seconds, but beware of some,
*                             like Aztec C, which return other units. The LOOPS define is initially set for 50,000 loops.
*                             If you have a machine with large integers and is very fast, please change this number to 500,000 to
*                             get better accuracy. Please select the way to measure the execution time using the TIME define.
*                             For single-user machines, time(2) is adequate. For multiuser machines where you cannot get
*                             single-user access, use the times(2) function. If you have neither, use a stopwatch in the dead of
*                             night. Use a "printf" at the point marked "start timer" to begin your timings. DO NOT use the Unix
*                             time(1) command, as this will measure the total time to run this program, which will
*                             (erroneously) include the time to malloc(3) storage and to compute the time it takes to
*                             do nothing.
*
*          Run:               drynr; dryr
*
*          Results:           If you get any new machine/OS results, please send to:
*
*                                    ihnp4!castor!pcrat!rick
*
*                             and thanks to all that do. Space prevents listing the names of those who have provided some of
*                             these results. I'll be forwarding these results to Reinhold P. Weicker.
*
*          Note:              I order the list in increasing performance of the "with registers" benchmark. If the compiler
*                             doesn't provide register variables, then the benchmark is the same for both REG and NOREG.
*
*          PLEASE:            Send complete information about the machine type, clock speed, OS, and C manufacturer/version.
*                             If the machine is modified, tell me what was done. On Unix, execute uname -a and cc -V to get
*                             this info.
*
*          80x8x NOTE:        80x8x benchers: Please try to do all memory models for a particular compiler.
*
*          APOLOGY  (1/30/86):
*                   Well, I goofed things up! As pointed out by Haakon Bugge, the line of code marked "GOOF" below was
*                   missing from the Dhrystone distribution for the last several months. It *WAS* in a backup copy I made
*                   last winter, so no doubt it was victimized by sleepy fingers operating vi!
*
*                   The effect of the line missing is that the reported benchmarks are 15 percent too fast (at least on an
*                   80286). Now, this creates a dilemma- -do I throw out ALL the data so far collected and use only results
*                   from this (corrected) version, or do I just keep collecting data for the old version?
```

continued

```
*
*                    Since the data collected so far *is* valid as long as it is compared with like data, I have decided to
*                    keep TWO lists--one for the old benchmark, and one for the new. This also gives me an opportunity to
*                    correct one other error I made in the instructions for this benchmark. My experience with C
*                    compilers has been mostly with Unix 'pcc'-derived compilers, where the 'optimizer' simply fixes
*                    sloppy code generation (peephole optimization). But today, there exist C compiler optimizers that
*                    will actually perform optimization in the computer science sense of the word, by removing, for example,
*                    assignments to a variable whose value is never used. Dhrystone, unfortunately, provides lots of
*                    opportunities for this sort of optimization.
*
*                    I request that benchmarkers re-run this new, corrected version of Dhrystone, turning off or bypassing
*                    optimizers that perform more than peephole optimization. Please indicate the version of Dhrystone
*                    used when reporting the results to me.
*
* RESULTS BEGIN HERE
*
*-----------------------------------------DHRYSTONE VERSION 1.1 RESULTS BEGIN-----------------------------------------
*
* MACHINE                MICROPROCESSOR          OPERATING               COMPILER                DHRYSTONES/SEC.
* TYPE                                           SYSTEM                                          NO REG      REGS
* ---------------------  ----------------------  ----------------------  ----------------------  ----------  ----------
* Apple IIe              65C02-1.02 MHz          DOS 3.3                 Aztec CII v1.05i            37          37
* -                      Z80-2.5 MHz             CPM-80 v2.2             Aztec CII v1.05g            91          91
* -                      8086-8 MHz              RMX86 V6                Intel C-86 V2.0            197         203LM??
* IBM PC XT              8088-4.77 MHz           COHERENT 2.3.43         Mark Williams              259         275
* -                      8086-8 MHz              RMX86 V6                Intel C-86 V2.0            287         304 ??
* Fortune 32:16          68000-6 MHz             V7+sys3+4.1BSD          cc                         360         346
* PDP-11/34A             w/FP-11C                UNIX V7m                cc                         406         449
* Macintosh 512          68000-7.7 MHz           Mac ROM O/S             DeSmet(C ware)             625         625
* VAX-11/750             w/FPA                   UNIX 4.2BSD             cc                         831         852
* DataMedia 932          68000-10 MHz            UNIX sysV               cc                         837         888
* Plexus P35             68000-12.5 MHz          UNIX sysIII             cc                         835         894
* ATT PC7300             68010-10 MHz            UNIX 5.0.3              cc                         973        1034
* Compaq II              80286-8 MHz             MSDOS 3.1               MS C 3.0                  1086        1140 LM
* IBM PC AT              80286-7.5 MHz           Venix/286 SVR2          cc                        1159        1254 *15
* Compaq II              80286-8 MHz             MSDOS 3.1               MS C 3.0                  1190        1282 MM
* MicroVAX II            -                       Mach/4.3                cc                        1361        1385
* DEC uVAX II            -                       Ultrix-32m v1.1         cc                        1385        1399
* Compaq II              80286-8 MHz             MSDOS 3.1               MS C 3.0                  1351        1428
* VAX-11/780             -                       UNIX 4.2BSD             cc                        1417        1441
* VAX-780/MA780          -                       Mach/4.3                cc                        1428        1470
* VAX-11/780             -                       UNIX 5.0.1              cc 4.1.1.31               1650        1640
* Ridge 32C V1           -                       ROS 3.3                 Ridge C (older)           1628        1695
* Gould PN6005           -                       UTX 1.1c+ (4.2)         cc                        1732        1884
* Gould PN9080           custom ECL              UTX-32 1.1C             cc                        4745        4992
* VAX-784                -                       Mach/4.3                cc                        5263        5555 &4
* VAX 8600               -                       4.3 BSD                 cc                        6329        6423
* Amdahl 5860            -                       UTS sysV                cc 1.22                  28,735      28,846
* IBM3090/200            -                       ?                       ?                        31,250      31,250
*
*
* ----------------------------------------- DHRYSTONE VERSION 1.0 RESULTS BEGIN -----------------------------------------
*
* MACHINE                MICROPROCESSOR          OPERATING               COMPILER                DHRYSTONES/SEC.
* TYPE                                           SYSTEM                                          NO REG      REGS
* ---------------------  ----------------------  ----------------------  ----------------------  ----------  ----------
* Commodore 64           6510-1 MHz              C64 ROM                 C Power 2.8                36          36
* HP-110                 8086-5.33 MHz           MS-DOS 2.11             Lattice 2.14              284         284
* IBM PC XT              8088-4.77 MHz           PC/IX                   cc                        271         294
* CCC 3205               -                       Xelos(SVR2)             cc                        558         592
* Perq-II                2901 bitslice           Accent S5c              cc (CMU)                  301         301
* IBM PC XT              8088-4.77 MHz           COHERENT 2.3.43         Mark Williams cc          296         317
* Cosmos                 68000-8 MHz             UniSoft                 cc                        305         322
* IBM PC XT              8088-4.77 MHz           Venix/86 2.0            cc                        297         324
* DEC PRO 350            11/23                   Venix/PRO SVR2          cc                        299         325
* IBM PC                 8088-4.77 MHz           MS-DOS 2.0              b16cc 2.0                 310         340
* PDP11/23               11/23                   Venix (V7)              cc                        320         358
* Commodore Amiga                                ?                       Lattice 3.02              368         371
* PC XT                  8088-4.77 MHz           Venix/86 SYS V          cc                        339         377
* IBM PC                 8088-4.77 MHz           MS-DOS 2.0              CI-C86 2.20M              390         390
* IBM PC XT              8088-4.77 MHz           PC-DOS 2.1              Wizard 2.1                367         403
* IBM PC XT              8088-4.77 MHz           PC-DOS 3.1              Lattice 2.15              403         403 @
* Colex DM-6             68010-8 MHz             Unisoft SYSV            cc                        378         410
* IBM PC                 8088-4.77 MHz           PC-DOS 3.1              Datalight 1.10            416         416
* IBM PC                 NEC V20-4.77 MHz        MS-DOS 3.1              MS 3.1                    387         420
* IBM PC XT              8088-4.77 MHz           PC-DOS 2.1              Microsoft 3.0             390         427
```

* IBM PC	NEC V20-4.77 MHz	MS-DOS 3.1	MS 3.1 (186)	393	427
* PDP-11/34	-	Unix V7M	cc	387	438
* IBM PC	8088, 4.77 MHz	PC-DOS 2.1	Aztec C v3.2d	423	454
* Tandy 1000	V20, 4.77 MHz	MS-DOS 2.11	Aztec C v3.2d	423	458
* Tandy TRS-16B	68000-6 MHz	Xenix 1.3.5	cc	438	458
* PDP-11/34	-	RSTS/E	decus c	438	495
* Onyx C8002	Z8000-4 MHz	IS/1 1.1 (V7)	cc	476	511
* Tandy TRS-16B	68000-6 MHz	Xenix 1.3.5	Green Hills	609	617
* DEC PRO 380	11/73	Venix/PRO SVR2	cc	577	628
* FHL QT+	68000-10 MHz	Os9/68000	version 1.3	603	649 FH
* Apollo DN550	68010-? MHz	AegisSR9/IX	cc 3.12	666	666
* HP-110	8086-5.33 MHz	MS-DOS 2.11	Aztec C	641	676
* ATT PC6300	8086-8 MHz	MS-DOS 2.11	b16cc 2.0	632	684
* IBM PC AT	80286-6 MHz	PC-DOS 3.0	CI-C86 2.1	666	684
* Tandy 6000	68000-8 MHz	Xenix 3.0	cc	694	694
* IBM PC AT	80286-6 MHz	Xenix 3.0	cc	684	704 MM
* Macintosh	68000-7.8 MHz 2M	Mac Rom	Mac C 32 bit int	694	704
* Macintosh	68000-7.7 MHz	-	MegaMax C 2.0	661	709
* Macintosh 512	68000-7.7 MHz	Mac ROM O/S	DeSmet(C ware)	714	714
* IBM PC AT	80286-6 MHz	Xenix 3.0	cc	704	714 LM
* Codata 3300	68000-8 MHz	UniPlus+ (v7)	cc	678	725
* WICAT MB	68000-8 MHz	System V	WICAT C 4.1	585	731
* Cadmus 9000	68010-10 MHz	Unix	cc	714	735
* AT&T 6300	8086-8 MHz	Venix/86 SVR2	cc	668	743
* Cadmus 9790	68010-10 MHz 1MB	SVR0,Cadmus3.7	cc	720	747
* NEC PC9801F	8086-8 MHz	PC-DOS 2.11	Lattice 2.15	768	- @
* ATT PC6300	8086-8 MHz	MS-DOS 2.11	CI-C86 2.20M	769	769
* Burroughs XE550	68010-10 MHz	Centix 2.10	cc	769	769 CT1
* EAGLE/TURBO	8086-8 MHz	Venix/86 SVR2	cc	696	779
* ALTOS 586	8086-10 MHz	Xenix 3.0b	cc	724	793
* DEC 11/73	J-11 micro	Ultrix-11 V3.0	cc	735	793
* ATT 3B2/300	WE32000-? MHz	Unix 5.0.2	cc	735	806
* Apollo DN320	68010-? MHz	AegisSR9/IX	cc 3.12	806	806
* IRIS-2400	68010-10 MHz	Unix System V	cc	772	829
* Atari 520ST	68000-8 MHz	TOS	DigResearch	839	846
* IBM PC AT	80286-6 MHz	PC-DOS 3.0	MS 3.0(large)	833	847 LM
* WICAT MB	68000-8 MHz	System V	WICAT C 4.1	675	853 S
* VAX-11/750	-	Ultrix 1.1	4.2BSD cc	781	862
* CCC 7350A	68000-8 MHz	UniSoft V.2	cc	821	875
* VAX-11/750	-	Unix 4.2bsd	cc	862	877
* Fast Mac	68000-7.7 MHz	-	MegaMax C 2.0	839	904 +
* IBM PC XT	8086-9.54 MHz	PC-DOS 3.1	Microsoft 3.0	833	909 C1
* DEC 11/44		Ultrix-11 V3.0	cc	862	909
* Macintosh	68000-7.8 MHz 2M	Mac Rom	Mac C 16 bit int	877	909 S
* CCC 3210	-	Xelos R01(SVR2)	cc	849	924
* CCC 3220	-	Ed. 7 v2.3	cc	892	925
* IBM PC AT	80286-6 MHz	Xenix 3.0	cc -i	909	925
* AT&T 6300	8086, 8 MHz	MS-DOS 2.11	Aztec C v3.2d	862	943
* IBM PC AT	80286-6 MHz	Xenix 3.0	cc	892	961
* VAX-11/750	w/FPA	Eunice 3.2	cc	914	976
* IBM PC XT	8086-9.54 MHz	PC-DOS 3.1	Wizard 2.1	892	980 C1
* IBM PC XT	8086-9.54 MHz	PC-DOS 3.1	Lattice 2.15	980	980 C1
* Plexus P35	68000-10 MHz	Unix System III	cc	984	980
* PDP-11/73	KDJ11-AA 15 MHz	Unix V7M 2.1	cc	862	981
* VAX-11/750	w/FPA	Unix 4.3bsd	cc	994	997
* IRIS-1400	68010-10 MHz	Unix System V	cc	909	1000
* IBM PC AT	80286-6 MHz	Venix/86 2.1	cc	961	1000
* IBM PC AT	80286-6 MHz	PC-DOS 3.0	b16cc 2.0	943	1063
* Zilog S8000/11	Z8001-5.5 MHz	Zeus 3.2	cc	1011	1084
* NSC ICM-3216	NSC 32016-10 MHz	Unix SVR2	cc	1041	1084
* IBM PC AT	80286-6 MHz	PC-DOS 3.0	MS 3.0(small)	1063	1086
* VAX-11/750	w/FPA	VMS	VAX-11 C 2.0	958	1091
* Stride	68000-10 MHz	System-V/68	cc	1041	1111
* Plexus P/60	MC68000-12.5 MHz	Unix SYSIII	Plexus	1111	1111
* ATT PC7300	68010-10 MHz	Unix 5.0.2	cc	1041	1111
* CCC 3230	-	Xelos R01(SVR2)	cc	1040	1126
* Stride	68000-12 MHz	System-V/68	cc	1063	1136
* IBM PC AT	80286-6 MHz	Venix/286 SVR2	cc	1056	1149
* Plexus P/60	MC68000-12.5 MHz	Unix SYSIII	Plexus	1111	1163 T
* IBM PC AT	80286-6 MHz	PC-DOS 3.0	Datalight 1.10	1190	1190
* ATT PC6300+	80286-6 MHz	MS-DOS 3.1	b16cc 2.0	1111	1219
* IBM PC AT	80286-6 MHz	PC-DOS 3.1	Wizard 2.1	1136	1219
* Sun 2/120	68010-10 MHz	Sun 4.2BSD	cc	1136	1219
* IBM PC AT	80286-6 MHz	PC-DOS 3.0	CI-C86 2.20M	1219	1219
* WICAT PB	68000-8 MHz	System V	WICAT C 4.1	998	1226

continued

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* MASSCOMP 500	68010-10 MHz	RTU V3.0	cc (V3.2)	1156	1238
* Alliant FX/8	IP (68012-12 MHz)	Concentrix	cc -ip;exec -i	1170	1243 FX
* Cyb DataMate	68010-12.5 MHz	Uniplus 5.0	Unisoft cc	1162	1250
* PDP 11/70	-	Unix 5.2	cc	1162	1250
* IBM PC AT	80286-6 MHz	PC-DOS 3.1	Lattice 2.15	1250	1250
* IBM PC AT	80286-7.5 MHz	Venix/86 2.1	cc	1190	1315 *15
* Sun2/120	68010-10 MHz	Standalone	cc	1219	1315
* Intel 380	80286-8 MHz	Xenix R3.0up1	cc	1250	1315 *16
* Sequent Balance 8000	NS32032-10 MHz	Dynix 2.0	cc	1250	1315 N12
* IBM PC/DSI-32	32032-10 MHz	MS-DOS 3.1	Green Hills 2.14	1282	1315 C3
* ATT 3B2/400	WE32100-? MHz	Unix 5.2	cc	1315	1315
* CCC 3250XP	-	Xelos R01(SVR2)	cc	1215	1318
* IBM PC RT 032	RISC(801?)? MHz	BSD 4.2	cc	1248	1333 RT
* DG MV4000	-	AOS/VS 5.00	cc	1333	1333
* IBM PC AT	80286-8 MHz	Venix/86 2.1	cc	1275	1380 *16
* IBM PC AT	80286-6 MHz	MS-DOS 3.0	Microsoft 3.0	1250	1388
* ATT PC6300+	80286-6 MHz	MS-DOS 3.1	CI-C86 2.20M	1428	1428
* COMPAQ/286	80286-8 MHz	Venix/286 SVR2	cc	1326	1443
* IBM PC AT	80286-7.5 MHz	Venix/286 SVR2	cc	1333	1449 *15
* WICAT PB	68000-8 MHz	System V	WICAT C 4.1	1169	1464 S
* Tandy II/6000	68000-8 MHz	Xenix 3.0	cc	1384	1477
* MicroVAX II	-	Mach/4.3	cc	1513	1536
* WICAT MB	68000-12.5 MHz	System V	WICAT C 4.1	1246	1537
* IBM PC AT	80286-9 MHz	SCO Xenix V	cc	1540	1556 *18
* Cyb DataMate	68010-12.5 MHz	Uniplus 5.0	Unisoft cc	1470	1562 S
* VAX-11/780	-	Unix 5.2	cc	1515	1562
* MicroVAX-II	-	-	-	1562	1612
* VAX-780/MA780		Mach/4.3	cc	1587	1612
* VAX-11/780	-	Unix 4.3bsd	cc	1646	1662
* Apollo DN660	-	AegisSR9/IX	cc 3.12	1666	1666
* ATT 3B20	-	Unix 5.2	cc	1515	1724
* NEC PC-98XA	80286-8 MHz	PC-DOS 3.1	Lattice 2.15	1724	1724 @
* HP9000-500	B series CPU	HP-UX 4.02	cc	1724	-
* Ridge 32C V1	-	ROS 3.3	Ridge C (older)	1776	-
* IBM PC/STD	80286-8 MHz	MS-DOS 3.0	Microsoft 3.0	1724	1785 C2
* WICAT MB	68000-12.5 MHz	System V	WICAT C 4.1	1450	1814 S
* WICAT PB	68000-12.5 MHz	System V	WICAT C 4.1	1530	1898
* DEC-2065	KL10-Model B	TOPS-20 6.1FT5	Port. C Comp.	1937	1946
* Gould PN6005	-	UTX 1.1(4.1BSD)	cc	1675	1964
* DEC2060	KL-10	TOPS-20	cc	2000	2000 NM
* Intel 310AP	80286-8 MHz	Xenix 3.0	cc	1893	2009
* VAX-11/785	-	Unix 5.2	cc	2083	2083
* VAX-11/785	-	VMS	VAX-11 C 2.0	2083	2083
* VAX-11/785	-	Unix SVR2	cc	2123	2083
* VAX-11/785	-	ULTRIX-32 1.1	cc	2083	2091
* VAX-11/785	-	Unix 4.3bsd	cc	2135	2136
* WICAT PB	68000-12.5 MHz	System V	WICAT C 4.1	1780	2233 S
* Pyramid 90x	-	OSx 2.3	cc	2272	2272
* Pyramid 90x	FPA,cache,4Mb	OSx 2.5	cc no -O	2777	2777
* Pyramid 90x	w/cache	OSx 2.5	cc w/-O	3333	3333
* IBM-4341-II	-	VM/SP3	Waterloo C 1.2	3333	3333
* IRIS-2400T	68020-16.67 MHz	Unix System V	cc	3105	3401
* Celerity C-1200	?	Unix 4.2BSD	cc	3485	3468
* SUN 3/75	68020-16.67 MHz	SUN 4.2 V3	cc	3333	3571
* IBM-4341	Model 12	UTS 5.0	?	3685	3685
* SUN 3/160	68020-16.67 MHz	Sun 4.2 V3.0A	cc	3381	3764
* Sun 3/180	68020-16.67 MHz	Sun 4.2	cc	3333	3846
* IBM-4341	Model 12	UTS 5.0	?	3910	3910 MN
* MC 5400	68020-16.67 MHz	RTU V3.0	cc (V4.0)	3952	4054
* Intel 386/20	80386-12.5 MHz	PMON debugger	Intel C386v0.2	4149	4386
* NCR Tower32	68020-16.67 MHz	SYS 5.0 Rel 2.0	cc	3846	4545
* MC 5600/5700	68020-16.67 MHz	RTU V3.0	cc (V4.0)	4504	4746 %
* Intel 386/20	80386-12.5 MHz	PMON debugger	Intel C386v0.2	4534	4794 i1
* Intel 386/20	80386-16 MHz	PMON debugger	Intel C386v0.2	5304	5607
* Gould PN9080	custom ECL	UTX-32 1.1C	cc	5369	5676
* Gould 1460-342	ECL proc	UTX/32 1.1/c	cc	5342	5677 G1
* VAX-784	-	Mach/4.3	cc	5882	5882 &4
* Intel 386/20	80386-16 MHz	PMON debugger	Intel C386v0.2	5801	6133 i1
* VAX 8600	-	Unix 4.3bsd	cc	7024	7088
* VAX 8600	-	VMS	VAX-11 C 2.0	7142	7142
* Alliant FX/8	CE	Concentrix	cc -ce;exec -c	6952	7655 FX
* CCI POWER 6/32		COS(SV+4.2)	cc	7500	7800
* CCI POWER 6/32		POWER 6 Unix/V	cc	8236	8498
* CCI POWER 6/32		4.2 Rel. 1.2b	cc	8963	9544
* Sperry (CCI Power 6)		4.2BSD	cc	9345	10,000
* CRAY-X-MP/12	105 MHz	COS 1.14	Cray C	10,204	10,204

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* IBM-3083              -           UTS 5.0 Rel 1     cc              16,666   12,500
* CRAY-1A               80 MHz      CTSS              Cray C 2.0      12,100   13,888
* IBM-3083              -           VM/CMS HPO 3.4    Waterloo C 1.2  13,889   13,889
* Amdahl 470 V/8                    UTS/V 5.2         cc v1.23        15,560   15,560
* CRAY-X-MP/48          105 MHz     CTSS              Cray C 2.0      15,625   17,857
* Amdahl 580            -           UTS 5.0 Rel 1.2   cc v1.5        23,076   23,076
* Amdahl 5860                       UTS/V 5.2         cc v1.23        28,970   28,970
*
* NOTE
*
*  *     Crystal changed from 'stock' to listed value.
*  +     This Macintosh was upgraded from 128K to 512K in such a way that the new 384K of memory is not slowed down by video
*        generator accesses.
*  %     Single processor; MC == MASSCOMP.
*  NM    A version 7 C compiler written at New Mexico Tech.
*  @     Vanilla Lattice compiler used with MicroPro standard library.
*  S     Shorts used instead of ints.
*  T     With Chris Torek's patches (whatever they are).
*        For WICAT Systems: MB=MultiBus, PB=Proprietary Bus.
*  LM    Large Memory Model. (Otherwise, all 80x8x results are small model).
*  MM    Medium Memory Model. (Otherwise, all 80x8x results are small model).
*  C1    Univation PC TURBO Coprocessor; 9.54-MHz 8086, 640K RAM
*  C2    Seattle Telecom STD-286 board.
*  C3    Definicon DSI-32 coprocessor.
*  C?    Unknown coprocessor board.
*  CT1   Convergent Technologies MegaFrame, 1 processor.
*  MN    Using Mike Newton's 'optimizer' (see net.sources).
*  G1    This Gould machine has two processors and was able to run two Dhrystone benchmarks in parallel with
*        no slowdown.
*  FH    FHC == Frank Hogg Labs (Hazelwood Uniquad 2 in an FHL box).
*  FX    The Alliant FX/8 is a system consisting of 1-8 CEs (computation engines) and 1-12 IPs (interactive processors). Note
*        N8 applies.
*  RT    This is one of the RTs that CMU has been using for awhile. I'm not sure that this is identical to the machine that IBM is
*        selling to the public.
*  i1    Normally, the 386/20 starter kit has a 16K direct-mapped cache, which inserts two or three wait states on a write-
*        through. These results were obtained by disabling the write-through, or essentially turning the cache into
*        zero-wait-state memory.
*  Nnn   This machine has multiple processors, allowing "nn" copies of the benchmark to run in the same time as one copy.
*  &nn   This machine has "nn" processors, and the benchmark results were obtained by having all "nn" processors working on one
*        copy of Dhrystone. (Note this is different than Nnn. Salesmen like this measure.)
*  ?     I don't trust results marked with '?'. These were sent to me with either incomplete info, or with times that just don't
*        make sense. ?? means I think the performance is too poor; ?! means too good. If anybody can confirm these figures,
*        please respond.
*
* ABBREVIATIONS
*        CCC       Concurrent Computer Corp. (was Perkin-Elmer)
*        MC        Masscomp
*
*-----------------------------------------------------RESULTS END-----------------------------------------------------
*
*       The following program contains statements of a high-level programming language (C) in a distribution
*       considered representative:
*
*       assignments                     53%
*       control statements              32%
*       procedure, function calls       15%
*
*       100 statements are dynamically executed. The program is balanced with respect to the three aspects:
*               - statement type
*               - operand type (for simple data types)
*               - operand access
*                       operand global, local, parameter, or constant.
*
*       The combination of these three aspects is balanced only approximately.
*
*       The program does not compute anything meaningful, but it is syntactically and semantically correct.
*
*/

/* Accuracy of timings and human fatigue controlled by next two lines */
#define LOOPS   50000                   /* Use this for slow or 16-bit machines */
/*#define LOOPS   500000                /* Use this for faster machines */
```

continued

```
/* Compiler-dependent options */
#undef  NOENUM                          /* Define if compiler has no enums */
#undef  NOSTRUCTASSIGN                  /* Define if compiler can't assign structures */

/* define only one of the next two defines */
/*#define TIMES                         /* Use times(2) time function */
#define TIME                            /* Use time(2) time function */

/* define the granularity of your times(2) function (when used) */
#define HZ      60                      /* times(2) returns 1/60 second (most) */
/*#define HZ    100                     /* times(2) returns 1/100 second (WECo) */

/* for compatibility with goofed-up version */
/*#define GOOF                          /* Define if you want the goofed-up version */

#ifdef GOOF
char    Version[] = "1.0";
#else
char    Version[] = "1.1";
#endif

#ifdef  NOSTRUCTASSIGN
#define structassign(d, s)              memcpy(&(d), &(s), sizeof(d))
#else
#define structassign(d, s)              d = s
#endif

#ifdef  NOENUM
#define Ident1  1
#define Ident2  2
#define Ident3  3
#define Ident4  4
#define Ident5  5
typedef int     Enumeration;
#else
typedef enum    {Ident1, Ident2, Ident3, Ident4, Ident5} Enumeration;
#endif

typedef int     OneToThirty;
typedef int     OneToFifty;
typedef char    CapitalLetter;
typedef char    String30[31];
typedef int     Array1Dim[51];
typedef int     Array2Dim[51][51];

struct      Record
{
            struct Record               *PtrComp;
            Enumeration                 Discr;
            Enumeration                 EnumComp;
            OneToFifty                  IntComp;
            String30                    StringComp;
};

typedef struct Record RecordType;
typedef RecordType *  RecordPtr;
typedef int           boolean;

/* #define     NULL          0 */
#define TRUE        1
#define FALSE       0

#ifndef REG
#define REG
#endif

extern Enumeration              Func1();
extern boolean                  Func2();

#include <HD20:C:#include files:stdio.h>

#ifdef TIMES
#include <HD20:C:#include files:unix #includes:types.h>
#include <HD20:C:#include files:unix #includes:time.h>
#endif
```

```
main()
{
        Proc0();
        exit(0);
}

/*
 * Package 1
 */
int                     IntGlob;
boolean                 BoolGlob;
char                    Char1Glob;
char                    Char2Glob;
Array1Dim               Array1Glob;
Array2Dim               Array2Glob;
RecordPtr               PtrGlb;
RecordPtr               PtrGlbNext;

Proc0()
{
                OneToFifty                      IntLoc1;
                REG OneToFifty                  IntLoc2;
                OneToFifty                      IntLoc3;
                REG char                        CharLoc;
                REG char                        CharIndex;
                Enumeration                     EnumLoc;
                String30                        String1Loc;
                String30                        String2Loc;
                extern char                     *malloc();

#ifdef TIME
                long                            time();
                long                            starttime;
                long                            benchtime;
                long                            nulltime;
                register unsigned int           i;

                starttime = time( (long *) 0);
                for (i = 0; i < LOOPS; ++i);
                nulltime = time( (long *) 0) - starttime; /* Computes o'head of loop */
#endif
#ifdef TIMES
                time_t                          starttime;
                time_t                          benchtime;
                time_t                          nulltime;
                struct tm                       tms;
                register unsigned int           i;

                times(&tms); starttime = tms.tms_utime;
                for (i = 0; i < LOOPS; ++i);
                times(&tms);
                nulltime = tms.tms_utime - starttime; /* Computes overhead of looping */
#endif

                PtrGlbNext = (RecordPtr) malloc(sizeof(RecordType));
                PtrGlb = (RecordPtr) malloc(sizeof(RecordType));
                PtrGlb->PtrComp = PtrGlbNext;
                PtrGlb->Discr = Ident1;
                PtrGlb->EnumComp = Ident3;
                PtrGlb->IntComp = 40;
                strcpy(PtrGlb->StringComp, "DHRYSTONE PROGRAM, SOME STRING");
#ifndef GOOF
                strcpy(String1Loc, "DHRYSTONE PROGRAM, 1ST STRING");/*GOOF*/
#endif
                Array2Glob[8][7] = 10; /* Was missing in published program */

/*****************
 --  Start Timer  --
*****************/
#ifdef TIME
        starttime = time( (long *) 0);
#endif
#ifdef TIMES
        times(&tms); starttime = tms.tms_utime;
```

continued

```
#endif
        for (i = 0; i < LOOPS; ++i)
        {

                Proc5();
                Proc4();
                IntLoc1 = 2;
                IntLoc2 = 3;
                strcpy(String2Loc, "DHRYSTONE PROGRAM, 2ND STRING");
                EnumLoc = Ident2;
                BoolGlob = ! Func2(String1Loc, String2Loc);
                while (IntLoc1 < IntLoc2)
                {
                        IntLoc3 = 5 * IntLoc1 - IntLoc2;
                        Proc7(IntLoc1, IntLoc2, &IntLoc3);
                        ++IntLoc1;
                }
                Proc8(Array1Glob, Array2Glob, IntLoc1, IntLoc3);
                Proc1(PtrGlb);
                for (CharIndex = 'A'; CharIndex <= Char2Glob; ++CharIndex)
                        if (EnumLoc == Func1(CharIndex, 'C'))
                                Proc6(Ident1, &EnumLoc);
                IntLoc3 = IntLoc2 * IntLoc1;
                IntLoc2 = IntLoc3 / IntLoc1;
                IntLoc2 = 7 * (IntLoc3 - IntLoc2) - IntLoc1;
                Proc2(&IntLoc1);
        }

/-------------------
 --   Stop Timer   --
-------------------/

#ifdef TIME
        benchtime = time( (long *) 0) - starttime - nulltime;
        printf("Dhrystone(%s) time for %ld passes = %l \ n",
                Version,
                (long) LOOPS, benchtime);
        printf("This machine benchmarks at %ld Dhrystones/second \ n",
                ((long) LOOPS) / benchtime);
#endif
#ifdef TIMES
        times(&tms);
        benchtime = tms.tms_utime - starttime - nulltime;
        printf("Dhrystone(%s) time for %ld passes = %ld \ n",
                Version,
                (long) LOOPS, benchtime/HZ);
        printf("This machine benchmarks at %ld Dhrystones/second \ n",
                ((long) LOOPS) * HZ / benchtime);
#endif

}

Proc1(PtrParIn)
REG RecordPtr   PtrParIn;
{
#defineNextRecord          (*(PtrParIn->PtrComp))

        structassign(NextRecord, *PtrGlb);
        PtrParIn->IntComp = 5;
        NextRecord.IntComp = PtrParIn->IntComp;
        NextRecord.PtrComp = PtrParIn->PtrComp;
        Proc3(NextRecord.PtrComp);
        if (NextRecord.Discr == Ident1)
        {
                NextRecord.IntComp = 6;
                Proc6(PtrParIn->EnumComp, &NextRecord.EnumComp);
                NextRecord.PtrComp = PtrGlb->PtrComp;
                Proc7(NextRecord.IntComp, 10, &NextRecord.IntComp);
        }
        else
                structassign(*PtrParIn, NextRecord);

#undef   NextRecord
}
```

```
Proc2(IntParIO)
OneToFifty      *IntParIO;
{
        REG OneToFifty          IntLoc;
        REG Enumeration         EnumLoc;

        IntLoc = *IntParIO + 10;
        for(;;)
        {
                if (Char1Glob == 'A')
                {
                        --IntLoc;
                        *IntParIO = IntLoc - IntGlob;
                        EnumLoc = Ident1;
                }
                if (EnumLoc == Ident1)
                        break;
        }
}

Proc3(PtrParOut)
RecordPtr       *PtrParOut;
{
        if (PtrGlb != NULL)
                *PtrParOut = PtrGlb->PtrComp;
        else
                IntGlob = 100;
        Proc7(10, IntGlob, &PtrGlb->IntComp);
}

Proc4()
{
        REG boolean     BoolLoc;

        BoolLoc = Char1Glob == 'A';
        BoolLoc |= BoolGlob;
        Char2Glob = 'B';
}

Proc5()
{
        Char1Glob = 'A';
        BoolGlob = FALSE;
}

extern boolean Func3();

Proc6(EnumParIn, EnumParOut)
REG Enumeration   EnumParIn;
REG Enumeration   *EnumParOut;
{
        *EnumParOut = EnumParIn;
        if (! Func3(EnumParIn) )
                *EnumParOut = Ident4;
        switch (EnumParIn)
        {
        case Ident1:    *EnumParOut = Ident1; break;
        case Ident2:    if (IntGlob > 100) *EnumParOut = Ident1;
                        else *EnumParOut = Ident4;
                        break;
        case Ident3:    *EnumParOut = Ident2; break;
        case Ident4:    break;
        case Ident5:    *EnumParOut = Ident3;
        }
}

Proc7(IntParI1, IntParI2, IntParOut)
OneToFifty      IntParI1;
OneToFifty      IntParI2;
OneToFifty      *IntParOut;
{
        REG OneToFifty  IntLoc;

        IntLoc = IntParI1 + 2;
        *IntParOut = IntParI2 + IntLoc;
```

continued

```
}

Proc8(Array1Par, Array2Par, IntParI1, IntParI2)
Array1Dim       Array1Par;
Array2Dim       Array2Par;
OneToFifty      IntParI1;
OneToFifty      IntParI2;
{
        REG OneToFifty  IntLoc;
        REG OneToFifty  IntIndex;

        IntLoc = IntParI1 + 5;
        Array1Par[IntLoc] = IntParI2;
        Array1Par[IntLoc+1] = Array1Par[IntLoc];
        Array1Par[IntLoc+30] = IntLoc;
        for (IntIndex = IntLoc; IntIndex <= (IntLoc+1); ++IntIndex)
              Array2Par[IntLoc][IntIndex] = IntLoc;
        ++Array2Par[IntLoc][IntLoc-1];
        Array2Par[IntLoc+20][IntLoc] = Array1Par[IntLoc];
        IntGlob = 5;
}

Enumeration Func1(CharPar1, CharPar2)
CapitalLetter   CharPar1;
CapitalLetter   CharPar2;
{
        REG CapitalLetter       CharLoc1;
        REG CapitalLetter       CharLoc2;

        CharLoc1 = CharPar1;
        CharLoc2 = CharLoc1;
        if (CharLoc2 != CharPar2)
              return (Ident1);
        else
              return (Ident2);
}

boolean Func2(StrParI1, StrParI2)
String30        StrParI1;
String30        StrParI2;
{
        REG OneToThirty         IntLoc;
        REG CapitalLetter       CharLoc;

        IntLoc = 1;
        while (IntLoc <= 1)
              if (Func1(StrParI1[IntLoc], StrParI2[IntLoc+1]) == Ident1)
              {
                    CharLoc = 'A';
                    ++IntLoc;
              }
        if (CharLoc >= 'W' && CharLoc <= 'Z')
              IntLoc = 7;
        if (CharLoc == 'X')
              return(TRUE);
        else
        {
              if (strcmp(StrParI1, StrParI2) > 0)
              {
                    IntLoc += 7;
                    return (TRUE);
              }
              else
                    return (FALSE);
        }
}

boolean Func3(EnumParIn)
REG Enumeration EnumParIn;
{
        REG Enumeration EnumLoc;

        EnumLoc = EnumParIn;
        if (EnumLoc == Ident3) return (TRUE);
        return (FALSE);
}
```

```
#ifdef   NOSTRUCTASSIGN
memcpy(d, s, l)
register char   *d;
register char   *s;
register int    l;
{
        while (l--) *d++ = *s++;
}
#endif
```

FIB.C Accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
#include <stdio.h>

#define NTIMES 10 /* number of times to compute Fibonacci value */
#define NUMBER 24 /* biggest one we can compute with 16 bits */

main()
        /* compute Fibonacci value */
    {
    int i;
    unsigned value, fib();

    printf("%d iterations: ", NTIMES);

    for (i = 1; i <= NTIMES; i++)
          value = fib(NUMBER);

    printf("Fibonacci(%d) = %u.\n", NUMBER, value);
    exit(0);
    }

unsigned fib(x)
                /* compute Fibonacci number recursively */
int x;
    {
    if (x > 2)
          return (fib(x - 1) + fib(x - 2));
    else
          return (1);
    }
```

FLOAT.C Accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
/* simple benchmark for testing floating-point speed of c libraries
  does repeated multiplications and divisions in a loop that is
  large enough to make the looping time insignificant */

#define CONST1  3.141597E0
#define CONST2  1.7839032E4
#define COUNT   10000

main()
      {
      double a, b, c;
      int i;

      a = CONST1;
      b = CONST2;
      for (i = 0; i < COUNT; ++i)
            {
            c = a * b;
```

continued

```
        c = c / a;
        c = a * b;
        c = c / a;
        c = a * b;
        c = c / a;
        c = a * b;
        c = c / a;
        c = a * b;
        c = c / a;
        c = a * b;
        c = c / a;
        c = a * b;
        c = c / a;
        }
printf ("Done\n");
}
```

SORT.C Accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
/* sorting benchmark- -calls randomly the number of times specified by
   MAXNUM to create an array of long integers, then does a quicksort
   on the array of longs. The program does this for the number of
   times specified by COUNT.
*/

#include "stdio.h"

#define MAXNUM 1000
#define COUNT 10
#define MODULUS ((long) 0x20000)

#define C 13849L
#define A 25173L

long seed = 7L;

long random( );

long buffer [MAXNUM] = {0};

main( )
        {
        int i, j;
        long temp;
/*
#include "startup.c"
*/
        printf ("Filling array and sorting %d times\n", COUNT);
        for (i = 0; i < COUNT; ++i)
                {
                for (j = 0; j < MAXNUM; ++j)
                        {
                        temp = random (MODULUS);
                                if (temp < 0L)
                                        temp = (-temp);
                                buffer[j] = temp;
                                }
                printf ("Buffer full, iteration %d\n", i);
                quick (0, MAXNUM - 1, buffer);
                        }
/*
#include "done.c"
*/
        }

quick (lo, hi, base)
        int lo, hi;
        long base [ ];
        {
```

```
    int i, j;
    long pivot, temp;

    if (lo < hi)
        {
        for (i = lo, j = hi-1, pivot = base [hi]; i < j; )
            {
            while (i < hi && base [i] <= pivot)
                ++i;
            while (j > lo && base [j] >= pivot)
                --j;
            if (i < j)
                {
                temp = base [i];
                base [i] = base [j];
                base [j] = temp;
                }
            }
        temp = base [i];
        base [i] = base [hi];
        base [hi] = temp;
        quick (lo, i - 1, base);
        quick (i + 1, hi, base);
        }
    }

long random (size)
    long size;
    {
    seed = seed * A + C;
    return (seed % size);
    }
```

SIEVE.C Accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
/*
Eratosthenes Sieve prime-number program in from BYTE January 1983
*/

#define TRUE    1
#define FALSE   0
#define size  8190

  char flags [size + 1];
main( )
  {
  int i, prime, k, count, iter;

  printf ("10 iterations\n");
  for (iter = 1; iter <= 10; iter++)          /* do program 10 times */
      {
      count = 0;                             /* prime counter */
      for (i = 0; i <= size; i++)             /* set all flags true */
         flags [i] = TRUE;
      for (i = 0; i <= size; i++)
         {
         if (flags [i])                      /* found a prime */
         {
         prime = i + i + 3;                   /* twice index + 3 */
                                              /* printf ("\n%d", prime); */
         for (k = i + prime; k <= size; k+= prime)
                  flags [k] = FALSE;         /* kill all multiple */
         count++;                               /* primes found */
         }
      }
  }
  printf ("%d primes.\n", count);         /* primes found on 10th pass */
}
```

SAVAGE.C Accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
/*
** savage.c -- floating-point speed and accuracy test. C version
** derived from BASIC version that appeared in Dr. Dobb's Journal,
** Sept. 1983, pp. 120-122.
*/

#define     ILOOP
            2500

extern      double
            tan(), atan(), exp(), log(), sqrt();

main()
{
int i;
double a;

            printf("start\n");
            a = 1.0;
            for (i = 1; i <= (ILOOP - 1); i++)
            a = tan(atan(exp(log(sqrt(a*a))))) + 1.0;
            printf("a = %20.14e\n", a);
            printf("done\n");
}
```

FILEIO.C Accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
/* file reading and writing benchmark
   sequentially writes a 65,000-byte file on disk
   generates random long numbers
   uses these modulo 65,000 to read and write strings of ODDNUM bytes
   with the file-handling system of the c package
   the random-number generator is set to a specific seed,
   so that all compilers should generate the same code
*/

#define ERROR -1
#define READERR 0

#define BEG 0
#define CURR 1
#define END 2
#define READ 0
#define WRITE 1
#define UPDATE 2

#define OKCLOSE 0
#define FILESIZE 65000L
#define COUNT 500

#define C 13849L
#define A 25173L
#define ODDNUM 23
long seed = 7L;

long random (), lseek ();

main ()
    {
    int i;
    long j, pos;
    int fd;
    char buffer [ODDNUM + 1];
```

```
    if ((fd = creat ("test.dat", WRITE)) == ERROR)
          abort ("Can't create data file\n");
    else  printf("File opened for sequential writing\n");
    for (j = 0; j < FILESIZE; ++j)
          if (write(fd, "x", 1) == ERROR)
                abort ("Unexpected EOF in writing data file\n");
    if (close (fd) != OKCLOSE)
          abort ("Error closing data file\n");
    else
          printf ("Normal termination writing data file\n");
    if ((fd = open ("test.dat", UPDATE)) == ERROR)
          abort ("Can't open data file for random reading and writing\n");
    else  printf ("File opened for random reading and writing\n");
    for (i = 0; i < COUNT; ++i)
          {
          j = random (FILESIZE);
          if (j < 0L)
                j = (-j);
          if (FILESIZE - j < ODDNUM)
                continue;
          if ((pos = lseek (fd, j, BEG)) == -1L)
                abort ("Error reading at random offset\n");
          if (read (fd, buffer, ODDNUM) == READERR)
                abort ("Error reading at random offset\n");
          j = random (FILESIZE);
          if (j < 0L)
                j = (-j);
          if (FILESIZE - j < ODDNUM)
                continue;
          if ((pos = lseek (fd, j, BEG)) == -1L)
                abort ("Error seeking to random offset\n");
          if (write (fd, buffer, ODDNUM) == READERR)
                abort ("Error writing at random offset\n");
          }
    if (close (fd) != OKCLOSE)
          abort ("Error closing data file\n");
    else
          printf ("Normal termination from random reading and writing\n");
    }

long random (size)
    long size;
    {
    seed = seed * A + C;
    return (seed % size);
    }
abort (message)
    char *message;
    {
    printf (message);
    exit (ERROR);
    }
```

WHET.C Accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C language benchmarks used in BYTE reviews.

```
/*
From hplabs!sdcrdcf!sdcsvax!dcdwest!ittatc!decvax!mcnc!rti-sel!scirtp!dfh
Sun Aug 25 12:55:29 1985
Relay-Version: version B 2.10.2  9/18/84; site amdahl.UUCP
Posting-Version: version B 2.10.2  9/5/84; site scirtp.UUCP
Path: amdahl!hplabs!sdcrdcf!sdcsvax!dcdwest!ittatc!decvax!mcnc!rti-sel!scirtp!dfh
From: dfh@scirtp.UUCP (David F. Hinnant)
Newsgroups: net.sources
Subject: Whetstone benchmark source in C - enclosed
Message-ID: <353@scirtp.UUCP>
Date: 25 Aug 85  19:55:29 GMT
Date Received: 27 Aug 85  08:15:18 GMT
Distribution: net
Organization: SCI Systems, Research Triangle Park, NC
Lines: 252
```

continued

July

```
Enclosed below is a C translation of the famous "Whetstone benchmark"
from the original Algol version. I have inserted printf( ) as a
compiler option. I think this translation is accurate. The only
listing accompanies the article "High-Tech Horsepower" by the BYTE editorial staff, July 1987, page 101. These are standard C
language benchmarks used in BYTE reviews.
Numbers I have to compare with are from an old Ridge-32 machine, and
these are from a Pascal translation (I caught one error in their
translation). If anyone has any numbers from FORTRAN, Pascal, or Algol
versions of the Whetstone, I would very much like to see them.

  David Hinnant
  SCI Systems Inc.
  {decvax, akgua}!mcnc!rti-sel!scirtp!dfh

P.S. There is a .signature file at the end of the listing. */
//=============================================================================================================================
/*
 *  Whetstone benchmark in C. This program is a translation of the
 *  original Algol version in "A Synthetic Benchmark" by H. J. Curnow
 *  and B. A. Wichman in Computer Journal, vol. 19, no. 1, February 1976.
 *
 *  Used to test compiler optimization and floating-point performance.
 *
 *  Compile by:   cc -O -s -o whet whet.c
 *  or:     cc -O -DPOUT -s -o whet whet.c
 *  if output is desired.
 */

#define ITERATIONS   10 /* 1 million Whetstone instructions */

#include "sane.h"
#include "stdio.h"

// #Options G H

#define POUT
#define Pout(n, j, k, x1, x2, x3, x4) timingOff;\
pout(n, j, k, x1, x2, x3, x4);timingOn
#define double extended
#define tickCount *((long *)0x16A)
#define timingOn ticks -= tickCount
#define timingOff ticks += tickCount

double  xx1, xx2, xx3, xx4, x, y, z, t, t1, t2;
double  e1[4];
int  i, j, k, l, n1, n2, n3, n4, n6, n7, n8, n9, n10, n11;
long   ticks;

main( )
{
 printf("\nWhetstone Benchmark\n\n");

 ticks = 0;

 timingOn;

 /* initialize constants */

 t = 0.499975;
 t1 = 0.50025;
 t2 = 2.0;

 /* set values of module weights */

 n1 = 0 * ITERATIONS;
 n2 = 12 * ITERATIONS;
 n3 = 14 * ITERATIONS;
 n4 = 345 * ITERATIONS;
 n6 = 210 * ITERATIONS;
 n7 = 32 * ITERATIONS;
 n8 = 899 * ITERATIONS;
 n9 = 616 * ITERATIONS;
 n10 = 0 * ITERATIONS;
 n11 = 93 * ITERATIONS;

/* MODULE 1: simple identifiers */
```

```
  xx1 = 1.0;
  xx2 = xx3 = xx4 = -1.0;

  for(i = 1; i <= n1; i += 1) {
   xx1 = ( xx1 + xx2 + xx3 - xx4 ) * t;
   xx2 = ( xx1 + xx2 - xx3 - xx4 ) * t;
   xx3 = ( xx1 - xx2 + xx3 + xx4 ) * t;
   xx4 = (-xx1 + xx2 + xx3 + xx4 ) * t;
  }
#ifdef POUT
  Pout(n1, n1, n1, xx1, xx2, xx3, xx4);
#endif

/* MODULE 2: array elements */

  e1[0] = 1.0;
  e1[1] = e1[2] = e1[3] = -1.0;

  for (i = 1; i <= n2; i +=1) {
   e1[0] = ( e1[0] + e1[1] + e1[2] - e1[3] ) * t;
   e1[1] = ( e1[0] + e1[1] - e1[2] + e1[3] ) * t;
   e1[2] = ( e1[0] - e1[1] + e1[2] + e1[3] ) * t;
   e1[3] = (-e1[0] + e1[1] + e1[2] + e1[3] ) * t;
  }
#ifdef POUT
  Pout(n2, n3, n2, e1[0], e1[1], e1[2], e1[3]);
#endif

/* MODULE 3: array as parameter */

  for (i = 1; i <= n3; i += 1)
   pa(e1);
#ifdef POUT
  Pout(n3, n2, n2, e1[0], e1[1], e1[2], e1[3]);
#endif

/* MODULE 4: conditional jumps */

  j = 1;
  for (i = 1; i <= n4; i += 1) {
    if (j == 1)
     j = 2;
    else
     j = 3;

    if (j > 2)
     j = 0;
    else
     j = 1;

    if (j < 1 )
     j = 1;
    else
     j = 0;
  }
#ifdef POUT
  Pout(n4, j, j, xx1, xx2, xx3, xx4);
#endif

/* MODULE 5: omitted */

/* MODULE 6: integer arithmetic */

  j = 1;
  k = 2;
  l = 3;

  for (i = 1; i <= n6; i += 1) {
   j = j * (k - j) * (l - k);
   k = l * k - (l - j) * k;
   l = (l - k) * (k + j);

   e1[l - 2] = j + k + l;   /* C arrays are zero-based */
   e1[k - 2] = j * k * l;
  }
```

continued

```
#ifdef POUT
 Pout(n6, j, k, e1[0], e1[1], e1[2], e1[3]);
#endif

/* MODULE 7: trig. functions */

 x = y = 0.5;

 for(i = 1; i <= n7; i +=1) {
  x = t * atan(t2*sin(x)*cos(x)/(cos(x+y)+cos(x-y)-1.0));
  y = t * atan(t2*sin(y)*cos(y)/(cos(x+y)+cos(x-y)-1.0));
 }
#ifdef POUT
 Pout(n7, j, k, x, x, y, y);
#endif

/* MODULE 8: procedure calls */

 x = y = z = 1.0;

 for (i = 1; i <= n8; i +=1)
  p3(x, y, &z);
#ifdef POUT
 Pout(n8, j, k, x, y, z, z);
#endif

/* MODULE 9: array references */

 j = 1;
 k = 2;
 l = 3;

 e1[0] = 1.0;
 e1[1] = 2.0;
 e1[2] = 3.0;

 for(i = 1; i <= n9; i += 1)
  p0( );
#ifdef POUT
 Pout(n9, j, k, e1[0], e1[1], e1[2], e1[3]);
#endif

/* MODULE 10: integer arithmetic */

 j = 2;
 k = 3;

 for(i = 1; i <= n10; i +=1) {
  j = j + k;
  k = j + k;
  j = k - j;
  k = k - j - j;
 }
#ifdef POUT
 Pout(n10, j, k, xx1, xx2, xx3, xx4);
#endif

/* MODULE 11: standard functions */

 x = 0.75;
 for(i = 1; i <= n11; i +=1)
  x = sqrt( exp( log(x) / t1));

#ifdef POUT
 Pout(n11, j, k, x, x, x, x);
#endif

 timingOFF;
 printf("\nWhetstone runs in %0.2f seconds. %0.2f whets/second\n",
   ticks/60.0, 60000000.0/ticks);
 getchar( );
 exit(0);

}
```

```
pa(e)
double e[4];
{
  register int j;

  j = 0;
    lab:
  e[0] = ( e[0] + e[1] + e[2] - e[3] ) * t;
  e[1] = ( e[0] + e[1] - e[2] + e[3] ) * t;
  e[2] = ( e[0] - e[1] + e[2] + e[3] ) * t;
  e[3] = ( -e[0] + e[1] + e[2] + e[3] ) / t2;
  j += 1;
  if (j < 6)
    goto lab;
}

p3(x, y, z)
double x, y, *z;
{
  x = t * (x + y);
  y = t * (x + y);
  *z = (x + y) / t2;
}

p0( )
{
  e1[j] = e1[k];
  e1[k] = e1[l];
  e1[l] = e1[j];
}

#ifdef POUT
pout(n, j, k, x1, x2, x3, x4)
int n, j, k;
double x1, x2, x3, x4;
{
  printf("%5d %5d %5d %11.3e %11.3e %11.3e %11.3e\n",
   n, j, k, x1, x2, x3, x4);
}
#endif

/*
=============================================================================================================================
   David Hinnant
   SCI Systems Inc.
   {decvax, akgua}!mcnc!rti-sel!scirtp!dfh

*/
```

USORT.PAS Program in Turbo Pascal 3.0 for the IBM PC and compatibles. From the article "Focus on Algorithms: Sorting out the Sorts" by Dick Pountain, July 1987, page 275.

```
program USORT;
const CR = #13;   { carriage return character }
type letters = 'a'..'z';
  wordtype = string[16];
  nodeptr = ^nodetype;
  nodetype = record
info: wordtype;
next: nodeptr
end;
var inputFile,outputFile: text;
  inputFilename, outputFilename: string[127];
  chr,firstletter: char;
  sortList: array[letters] of nodeptr;   { the array of 26 lists }
  i: letters;
  word: wordtype;
procedure InitFiles;
begin   { open input and output files }
```

continued

```
 inputFilename := paramSTR(1);
 Assign(inputFile,inputFilename);
 Reset(inputFile);
 outputFilename := paramSTR(2);
 Assign(outputFile, outputFilename);
 Rewrite(outputFile);
end;
procedure GetWord(VAR infile: text; VAR word: wordtype);
begin  { read a cleaned-up word from the input file }
 word := '';  { initialize to blank }
 repeat
  read(infile,chr);
  if chr in ['A'..'Z']  { convert all to lowercase }
  then chr := char(ord(chr)+32);
  if chr in ['a'..'z']  { only accept alpha characters }
  then word := word+chr;  { add to word being built }
 until (chr = ' ') or (chr = CR) or eof(infile)
end;
procedure Place(VAR list: nodeptr; word: wordtype);
var p,q,newnode: nodeptr;
  found: boolean;
begin  { insert new word into list in sorted position only if unique }
 q := nil;
 p := list;  { p points to head of list }
 found := false;
 while (p <> nil)  { not end of list and }
  and (not found) { word not already here and }
  and (word >= p^.info) do  { word alphabetically later than current }
  if p^.info = word  { does this node contain our word? }
  then found := true  { yes! word is already here }
  else begin
   q := p;  { remember this node and }
   p := p^.next  { move on to the next one }
  end; {while}
 if not found  { word isn't already here }
 then begin
  New(newnode);  { create a new node }
  newnode^.info := word;  { put word in its info field }
  if q = nil  { list was empty }
  then begin
   newnode^.next := list;  { newnode becomes first }
   list := newnode
  end
  else begin
   newnode^.next := q^.next;  { insert after node q }
   q^.next := newnode
  end
 end
end;
procedure SquirtOut(list: nodeptr; VAR outfile: text);
begin  { send sorted list to output file }
 while list <> nil
 begin
  writeln(outfile,list^.info);
  list := list^.next
 end
end;
begin  { main program }
 InitFiles;
 for i := 'a' to 'z' do sortList[i] := nil;  { initialize all the lists }
 while not eof(inputFile) do
 begin
  GetWord(inputFile,word);
  firstletter := word[1];  { get first letter }
  Place(sortList[firstletter],word)  { put word in proper place }
 end; {while}
 for i := 'a' to 'z' do SquirtOut(sortList[i],outputFile);
 writeln('Keywords are contained in ',outputFilename);
 Close(inputFile);
 Close(outputFile)
end.
```

LISTING2.TXT Contributed by David Gedeon. Accompanies "Programming Insight: Complex Math in Pascal," July 1987, page 121.

```
{$INCLUDE:'complex.int'}

IMPLEMENTATION OF complex;

TYPE
     stackpt = ^stack;
     stack = RECORD
       r,i: REAL;  {Holds real and imaginary parts of number}
       next,prev: stackpt;  {Links RECORDs of stack}
     END;

VAR zpt,zroot: stackpt;  {variable stack pointer and root position}

PROCEDURE push;     {Increments stack pointer; creates new RECORD only if next position = NIL}
     VAR zsav: stackpt;
      BEGIN
       IF (zpt^.next <> NIL) THEN zpt:= zpt^.next
       ELSE BEGIN
        zsav:= zpt;
        NEW(zpt);
        zpt^.prev:= zsav; zpt^.next:= NIL;
        zsav^.next:= zpt;
        END;
      END;

PROCEDURE pop;     {Decrements stack pointer}
     BEGIN
      IF (zpt^.prev <> NIL) THEN zpt:= zpt^.prev
      ELSE BEGIN  {In case of no previous element, pop zeros}
       zpt^.r:= 0.0; zpt^.i:= 0.0;
      END;
     END;

FUNCTION display:  {Argument (indx: INTEGER) declared in interface; extracts real or imaginary parts of current stack pointee}
BEGIN
      CASE indx OF
       1: display:= zpt^.r;
       2: display:= zpt^.i;
       OTHERWISE display:= 0;
       END;
      END;

PROCEDURE keyin;  {Argument (z: cmplx) declared in interface; equivalent of keying in numbers on calculator; pushes stack,
          inserts number at new pointee}
      BEGIN
       push;
       zpt^.r:= z[1];
       zpt^.i:= z[2];

      END;

PROCEDURE rkeyin;     {Argument (x: REAL) declared in interface}
                 {Similar to KEYIN except enters real number}
      BEGIN
       push;
       zpt^.r:= x;
       zpt^.i:= 0.0;
      END;

PROCEDURE enter;     {Copies current pointee onto stack}
      VAR a,b: REAL;
      BEGIN
       a:= zpt^.r; b:= zpt^.i;
       push;
       zpt^.r:= a; zpt^.i:= b;
       END;
```

continued

```
PROCEDURE clear;    {Resets stack pointer to root of list, zeros}
      BEGIN
       zpt:= zroot;
       zpt^.r:= 0.0; zpt^.i:= 0.0;
       END;

PROCEDURE negate;    {Negative of current stack pointee}
      BEGIN
       zpt^.r:= -zpt^.r;
       zpt^.i:= -zpt^.i;
       END;

PROCEDURE conjugate;  {Complex conjugate of current stack pointee}
      BEGIN
       zpt^.i:= - zpt^.i;
       END;

PROCEDURE invert;    {Inverse of current stack pointee}
      VAR mag: REAL;
      BEGIN
       mag:= (zpt^.r * zpt^.r) + (zpt^.i * zpt^.i);
       zpt^.r:= zpt^.r/mag;
       zpt^.i:= -zpt^.i/mag;
       END;

PROCEDURE add;      {Adds current and previous stack pointees; pops stack; result in new pointee}
      VAR a,b: REAL;
      BEGIN
        a:= zpt^.r; b:= zpt^.i;
       pop;
       zpt^.r:= zpt^.r + a;
       zpt^.i:= zpt^.i + b;
       END;


PROCEDURE subtract;    {Subtracts current from previous stack pointee; pops stack; result in new pointee}
      BEGIN
       negate;
       add;
       END;

PROCEDURE multiply;    {Multiplies current and previous stack pointees; pops stack; result in new pointee}
      VAR a,b,c,d: REAL;
      BEGIN
       a:= zpt^.r; b:= zpt^.i;
       pop;
       c:= (a * zpt^.r) - (b * zpt^.i);
       d:= (a * zpt^.i) + (b * zpt^.r);
       zpt^.r:= c;
       zpt^.i:= d;
       END;

PROCEDURE divide;   {Divides previous stack pointee by current; pops stack; result in new pointee}
      BEGIN
       invert;
       multiply;
       END;

PROCEDURE cexp;    {Complex exponential function of current stack pointee}
      VAR mag: REAL;
      BEGIN
       mag:= EXP(zpt^.r);
       zpt^.r:= mag*COS(zpt^.i);
       zpt^.i:= mag*SIN(zpt^.i);
       END;

PROCEDURE sinh;    {Complex hyperbolic sine of current stack pointee}
      VAR z: cmplx;
      BEGIN
       z[1]:= zpt^.r; z[2]:= zpt^.i;
       cexp;
       keyin(z); negate; cexp; subtract;
       zpt^.r:= 0.5*zpt^.r; zpt^.i:=0.5*zpt^.i;
       END;
```

```
PROCEDURE cosh;    {Complex hyperbolic cosine of current stack pointee}
      VAR z: cmplx;
      BEGIN
       z[1]:= zpt^.r; z[2]:= zpt^.i;
       cexp;
       keyin(z); negate; cexp; add;
       zpt^.r:= 0.5*zpt^.r; zpt^.i:= 0.5*zpt^.i;
       END;

BEGIN       {Initialize stack pointer; define it as head; zero pointee}

     NEW(zpt);
     zroot:= zpt;
     zpt^.prev:= NIL; zpt^.next:= NIL;
     clear;
END.
```

LISTING.TXT Contributed by David Gedeon. Accompanies "Programming Insight: Complex Math in Pascal," July 1987, page 121.

LISTING 1 - available operations

```
  PROCEDURE negate;
{Negative of current stack pointee}
  BEGIN
   zpt^.r := -zpt^.r;
   zpt^.i := -zpt^.i;
  END;

  PROCEDURE conjugate;
{Complex conjugate of current stack pointee}
  BEGIN
   zpt^.i := - zpt^.i;
  END;

  PROCEDURE invert;
{Inverse of current stack pointee}
  VAR mag: REAL;
  BEGIN
   mag := (zpt^.r * zpt^.r) + (zpt^.i * zpt^.i);
   zpt^.r :=  zpt^.r / mag;
   zpt^.i := -zpt^.i / mag;
  END;

  PROCEDURE add;
{Adds current and previous stack pointees; pops stack; result in new pointee}
  VAR a, b: REAL;
  BEGIN
   a := zpt^.r; b := zpt^.i;
   pop;
   zpt^.r := zpt^.r + a;
   zpt^.i := zpt^.i + b;
  END;

  PROCEDURE subtract;
{Subtracts current from previous stack pointee; pops stack; result in new pointee}
  BEGIN
   negate;
   add;
  END;

  PROCEDURE multiply;
{Multiplies current and previous stack pointees; pops stack; result in new pointee}
  VAR a, b, c, d: REAL;
  BEGIN
   a := zpt^.r; b := zpt^.i;
   pop;
   c := (a * zpt^.r) - (b * zpt^.i);
   d := (a * zpt^.i) + (b * zpt^.r);
```

continued

```
    zpt^.r := c;
    zpt^.i := d;
  END;

  PROCEDURE divide;
{Divides previous stack pointee by current; pops stack; result in new pointee}
  BEGIN
    invert;
    multiply;
  END;

  PROCEDURE cexp;
{Complex exponential function of current stack pointee}
  VAR mag: REAL;
  BEGIN
    mag := EXP(zpt^.r);
    zpt^.r := mag*COS(zpt^.i);
    zpt^.i := mag*SIN(zpt^.i);
  END;

  PROCEDURE sinh;
{Complex hyperbolic sine of current stack pointee}
  VAR z: cmplx;
  BEGIN
    z[1] := zpt^.r; z[2] := zpt^.i;
    cexp;
    keyin(z); negate; cexp; subtract;
    zpt^.r := 0.5*zpt^.r; zpt^.i := 0.5*zpt^.i;
  END;

  PROCEDURE cosh;
{Complex hyperbolic cosine of current stack pointee}
  VAR z: cmplx;
  BEGIN
    z[1] := zpt^.r; z[2] := zpt^.i;
    cexp;
    keyin(z); negate; cexp; add;
    zpt^.r := 0.5*zpt^.r; zpt^.i := 0.5*zpt^.i;
  END;
```

August

QDRGNINT.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    2    8
TA   OR
 2    5    1
TA   90R
 2    2    1
TA   180R
 2    7    3
TA   270R
 2    0    3
TA   ONBR
 2    0    4
TA   90NBR
 2    5    6
TA   180NBR
 2    2    6
TA   270NBR
 2    7    4
 1    1
 6    13   75   140
```

QDEKNGCH.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    4    4
TA   OR
 4    0    1    0    3
TA   90R
 4    2    3    2    3
TA   180R
 2    2    1    0    0
TA   270R
 2    0    1    0    0
 4    0    3    2    1
 5    7    100       140
```

QHILBRT.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    4    10
TA   OR
 4    1    0    3    4
TA   90R
 4    0    1    2    5
TA   180R
 4    0    1    2    6
TA   270R
 4    1    0    3    7
TA   OR
 4    6    7    4    0
TA   90R
 4    7    6    5    1
```

continued

```
TA   180R
 4    7    6    5    2
TA   270R
 4    6    7    4    3
TA   0R
 4    1    0    3    9
TA   90R
 4    6    7    4    8
 1    8
 10   5    80        190
```

QSRPNSK.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    9    8
TA   0R
 9    0    1    0    3    6    3    0    1    0
TA   90R
 9    1    2    1    0    7    0    1    2    1
TA   180R
 9    2    3    2    1    4    1    2    3    2
TA   270R
 9    3    0    3    2    5    2    3    0    3
TA   0BR
 3    4    4    4    0    0    0    0    0    0
TA   90BR
 3    5    5    5    0    0    0    0    0    0
TA   180BR
 3    6    6    6    0    0    0    0    0    0
TA   270BR
 3    7    7    7    0    0    0    0    0    0
 1    0
 5    4    50   100
```

QPENTGRE.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 5    6    5
TA   0R
 6    0    4    1    2    1    0
TA   72R
 6    1    0    2    3    2    1
TA   144R
 6    2    1    3    4    3    2
TA   216R
 6    3    2    4    0    4    3
TA   288R
 6    4    3    0    1    0    4
 1    0
 4    5    500       150
```

QSNOFLK.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 6    4    6
TA   0R
 4    0    1    5    0
TA   60R
 4    1    2    0    1
```

```
TA   120R
 4    2    3    1    2
TA   180R
 4    3    4    2    3
TA   240R
 4    4    5    3    4
TA   300R
 4    5    0    4    5
 1    0
 2    5   50     150
```

QAROHEAD.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 6    3   24
TA   OR
 3    0    7   17
TA   60R
 3    1    8   12
TA   120R
 3    2    9   13
TA   180R
 3    3   10   14
TA   240R
 3    4   11   15
TA   300R
 3    5    6   16
TA   OR
 3   23    1    6
TA   60R
 3   18    2    7
TA   120R
 3   19    3    8
TA   180R
 3   20    4    9
TA   240R
 3   21    5   10
TA   300R
 3   22    0   11
TA   OR
 3   12   23    1
TA   60R
 3   13   18    2
TA   120R
 3   14   19    3
TA   180R
 3   15   20    4
TA   240R
 3   16   21    5
TA   300R
 3   17   22    0
TA   OR
 3    7   17   18
TA   60R
 3    8   12   19
TA   120R
 3    9   13   20
TA   180R
 3   10   14   21
TA   240R
 3   11   15   22
TA   300R
 3    6   16   23
 4    2    7   17   22
 4    6  320    195
```

continued

QBRKINT.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    2    8
TA   ONBR
 2    0    1
TA   90NBR
 2    2    6
TA   180NBR
 2    2    3
TA   270NBR
 2    0    4
TA   OR
 2    5    4
TA   90R
 2    2    6
TA   180R
 2    7    6
TA   270R
 2    0    4
 1    0
 8    12   225  150
```

QBRICK.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    2    6
TA   OR
 2    0    1
TA   90R
 2    2    5
TA   180R
 2    2    3
TA   270R
 2    0    4
TA   OR
 2    1    4
TA   180R
 2    3    5
 2    0    2
 8    10   225  100
```

QLACE.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 12   3    24
TA   60R
 3    0    1    2
TA   120R
 3    3    4    5
TA   30R
 3    6    7    0
TA   300R
 3    1    8    9
TA   OR
 3    10   11   12
TA   330R
 3    7    0    1
TA   300R
 3    8    13   14
TA   OR
 3    15   10   16
```

```
TA   180R
 3    6     7     17
TA   150R
 3    11    18    3
TA   120R
 3    4     15    19
TA   180R
 3    13    6     20
TA   90R
 3    18    3     4
TA   240R
 3    11    18    21
TA   150R
 3    8     13    6
TA   60R
 3    7     0     22
TA   90R
 3    13    6     7
TA   270R
 3    0     1     8
TA   240R
 3    18    3     23
TA   330R
 3    4     15    10
TA   270R
 3    15    10    11
TA   210R
 3    1     8     13
TA   30R
 3    3     4     15
TA   210R
 3    10    11    18
 1    0
 10   6     10    180
```

QDRGBDRY.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    2     12
TA   0R
 2    0     5
TA   90R
 2    6     9
TA   180R
 2    7     2
TA   270R
 2    11    4
TA   0R
 1    8     0
TA   90R
 1    6     0
TA   180R
 1    10    0
TA   270R
 1    4     0
TA   0R
 2    0     1
TA   90R
 2    10    9
TA   180R
 2    3     2
TA   270R
 2    11    8
 4    0     5     6     11
 3    13    200   80
```

continued

QMDLQUIN.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4   5   8
TA   OR
 5   4   0   3   6   3
TA   90R
 5   5   1   0   7   0
TA   180R
 5   6   2   1   4   1
TA   270R
 5   7   3   2   5   2
TA   OR
 5   7   2   7   4   0
TA   90R
 5   4   3   4   5   1
TA   180R
 5   5   0   5   6   2
TA   270R
 5   6   1   6   7   3
 1   0
 5   5   300     190
```

QMOORE.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4   9   8
TA   OR
 9   0   1   2   6   2   3   7   6   5
TA   90R
 9   1   2   3   7   3   0   4   7   6
TA   180R
 9   2   3   0   4   0   1   5   4   7
TA   270R
 9   3   0   1   5   1   2   6   5   4
TA   OR
 9   1   2   3   7   6   2   6   5   4
TA   90R
 9   2   3   0   4   7   3   7   6   5
TA   180R
 9   3   0   1   5   4   0   4   7   6
TA   270R
 9   0   1   2   6   5   1   5   4   7
 1   0
 4   4   200     100
```

QSRPNSK2.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 8   2   8
TA   OR
 2   0   1
TA   315R
 2   2   0
TA   270R
 2   3   4
TA   90R
 2   2   5
TA   45R
 2   6   2
TA   225R
 2   0   3
```

```
TA   180R
 2    6    7
TA   135R
 2    3    6
 1    4
 5    11   580  150
```

QCHRSTRE.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 5    3    10
TA   0R
 3    9    0    6
TA   72R
 3    5    1    7
TA   144R
 3    6    2    8
TA   216R
 3    7    3    9
TA   288R
 3    8    4    5
TA   0R
 3    1    5    4
TA   72R
 3    2    6    0
TA   144R
 3    3    7    1
TA   216R
 3    4    8    2
TA   288R
 3    0    9    3
 1    5
 10   7    180    190
```

QDRGNCRD.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    2    8
TA   0R
 2    0    5
TA   90R
 2    2    5
TA   180R
 2    2    7
TA   270R
 2    0    7
TA   0BR
 2    4    1
TA   90BR
 2    6    1
TA   180BR
 2    6    3
TA   270BR
 2    4    3
 1    0
 6    11   400    150
```

continued

QDRGN.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 4    2    4
TA   OR
 2    0    1
TA   90R
 2    2    1
TA   180R
 2    2    3
TA   270R
 2    0    3
 1    0
 8    11   400  150
```

QGOSPER.CRV Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
 6    7    12
TA   OR
 7    0    7    9    2    0    0    11
TA   60R
 7    1    8    10   3    1    1    6
TA   120R
 7    2    9    11   4    2    2    7
TA   180R
 7    3    10   6    5    3    3    8
TA   240R
 7    4    11   7    0    4    4    9
TA   300R
 7    5    6    8    1    5    5    10
TA   0R
 7    5    6    6    8    3    1    6
TA   60R
 7    0    7    7    9    4    2    7
TA   120R
 7    1    8    8    10   5    3    8
TA   180R
 7    2    9    9    11   0    4    9
TA   240R
 7    3    10   10   6    1    5    10
TA   300R
 7    4    11   11   7    2    0    11
 3    0    4    2
 10   3    220       120
```

SZPAK.LST The following five listings accompany "Logic Grammars" by Stan Szpakowicz, August 1987, page 185.

Listing 1:

```
statements --> statement, [';'], statements.
statements --> [].
statement --> [skip].
statement --> [id(V)], [:=], expr.
statement --> [if], condition, [then], statements, [fi].
statement --> [while], condition, [do], statements, [od].

condition --> [not], relation.
condition --> relation.
relation --> expr, comp_op, expr.
comp_op --> ['='].
comp_op --> ['<'].
```

```
expression --> primary.
expression --> expression, arith_op, primary.

primary --> [id(V)].
primary --> [num(N)].

arith_op --> ['+'].
arith_op --> ['-'].
arith_op --> ['*'].
arith_op --> ['/'].
[end listing 1]
```

Listing 2:

```
/*1*/ statement(K, N) :-
       token(id(V), K, L), token(:=, L, M), expr(M, N).
/*2*/ expr(K, L) :- primary(K, L).
/*3*/ expr(K, N) :- expr(K, L), arith_op(L, M), primary(M, N).

/*4*/ primary(K, L) :- token(id(V), K, L).
/*5*/ primary(K, L) :- token(num(V), K, L).

/*6*/ arith_op(K, L) :- token(+, K, L).

/*7*/ token(T, [T|Ts], Ts).
[end listing 2]
```

Listing 3:

```
program(s(Stmt, Stmts)) -->
        statement(Stmt), [';'],
        statements(Stmts).

statements(s(Stmt, Stmts)) -->
        statement(Stmt), [';'],
        statements(Stmts).
statements(skip) --> [].

% a sequence of statements is represented as a nested term,
% for example s(Stmt1, s(Stmt2, s(Stmt3, skip))),
% where Stmt1, Stmt2, Stmt3 represent individual statements

statement(skip) --> [skip].
statement(let(V, E)) --> [id(V)], [:=], expr(E).
statement(if(C, Stmts)) -->
        [if], condition(C), [then], statements(Stmts), [fi].
statement(while(C, Stmts)) -->
        [while], condition(C), [do], statements(Stmts), [od].

condition(not(C)) --> [not], relation(C).
condition(C) --> relation(C).
relation(cond(Op, E1, E2)) --> expr(E1), comp_op(Op), expr(E2).

comp_op('=') --> ['='].
comp_op('<') --> ['<'].
[end listing 3]
```

Listing 4:

```
interm_code(s(Stmt, Stmts)) -->
        interm_code(Stmt), interm_code(Stmts).
interm_code(skip) --> [].
interm_code(let(V, E)) -->
        expr_interm_code(E), [store(V)].
interm_code(if(C, Stmts)) -->
        { newlabel(L) },
        cond_interm_code(not(C)),
        [jmp_cond(L)],
        interm_code(Stmts),
        [label(L)].
interm_code(while(C, Stmts)) -->
        { newlabel(L1) }, { newlabel(L2) },
        [label(L1)],
        cond_interm_code(not(C)),
        [jmp_cond(L2)],
        interm_code(Stmts),
        [jmp(L1)], [label(L2)].
[end listing 4]
```

continued

```
Listing 5:
The source program:
x := a;  y := n;  z := 1;
while not i < 1 do
  if y / 2 * 2 < y then
   z := z * x;
  fi;
  x := x * x;
  y := y / 2;
od; #
The resulting object code:
load(a)
store(x)
load(n)
store(y)
loadc(1)store(z)
label($lbl1)
loadc(1)
store($mem1)
load(i)
sub($mem1)
tst_neg
jmp_cond($lbl2)

etc.
[end listing 5]
```

SZPAK.BNL Contributed by Stan Szpakowicz.
Accompanies "Logic Grammars" by Stan Szpakowicz, August 1987, page 185. Written in Prolog using logic grammars.

```
%
% Note: In order to execute this program, a Prolog interpreter must support logic grammars or definite-clause grammars
%

% === main program ===
compile :-
        set_gensym( "$lbl" ),  set_gensym( "$mem" ),
        read_in( Chars ),                                   % (skips initial white space)
        lsym_list( LexSyms, Chars, [ ] ),                   % lexical analysis
        program( Tree, LexSyms, [ ] ),                      % syntactic analysis
        interm_code( Tree, Code, [ ] ),                     % code generation
        write_out( Code ), !.
compile :- write( 'Sorry' ), nl.

% read in a sequence of characters terminated by a #
read_in( Chars ) :- get( Ch ), read_in( Ch, Chars ).

read_in( 35, [ ] ) :- !.                    % #
read_in( Ch, [Ch | Chars] ) :- get0( Ch1 ), read_in( Ch1, Chars ).

% print the generated code one instruction per line
write_out( [ ] ).
write_out( [Instr | Instrs] ) :-
        write( Instr ), nl, write_out( Instrs ).

% === scanner ===
% list of lexical symbols
lsym_list( [LexSym | LexSyms] ) -->
        lsym( LexSym ), !, opt_space, lsym_list( LexSyms ).
lsym_list( [ ] ) --> [ ].

% one lexical symbol (input tokens are ASCII codes)
lsym( IdOrKwd ) --> letter( L ), alphanums( Ls ),
                    { name( Nm, [L | Ls] ) }, { wrap_name( Nm, IdOrKwd ) }.
lsym( num( N ) ) --> digit( D ), digits( Ds ),
                    { name( N, [D | Ds] ) }.
lsym( := ) --> [58], [61].                  % colon, equals
lsym( S ) --> [Ch], { name( S, [Ch] ) }.
```

```
% optional white space between lexical symbols
opt_space --> white_space, !, opt_space.
opt_space --> [].

% recognizing classes of ASCII codes
letter( L ) --> [L], { is_letter( L ) }.
digit( D ) --> [D], { is_digit( D ) }.
white_space --> [Ch], { is_white_space( Ch ) }.

is_letter( Ch ) :- 65 =< Ch, Ch =< 90.
is_letter( Ch ) :- 97 =< Ch, Ch =< 122.

is_digit( Ch ) :- 48 =< Ch, Ch =< 57.

is_white_space( 32 ).              % blank space
is_white_space( 13 ).              % new line (this would be 10 in Quintus Prolog)
is_white_space( 9 ).               % tab

% keywords and identifiers
alphanums( [L|Ls] ) --> letter( L ), alphanums( Ls ).
alphanums( [L|Ls] ) --> digit( L ), alphanums( Ls ).
alphanums( [] ) --> [].

wrap_name( Nm, Nm ) :- is_keyword( Nm ).
wrap_name( Nm, id( Nm ) ).

% table of keywords
is_keyword( if ).          is_keyword( then ).        is_keyword( fi ).
is_keyword( while ).       is_keyword( do ).          is_keyword( od ).
is_keyword( skip ).        is_keyword( not ).

% integers
digits( [D|Ds] ) --> digit( D ), digits( Ds ).
digits( [] ) --> [].

% === parser ===
program( s( Stmt, Stmts) ) -->
        statement( Stmt ), [';'],
        statements( Stmts ).

statements( s( Stmt, Stmts) ) -->
        statement( Stmt ), [';'], !,
        statements( Stmts ).
statements( skip ) --> [].
% a sequence of statements is represented as a nested term,
% for example s( Stmt1, s( Stmt2, s( Stmt3, skip ) ) ),
% where Stmt1, Stmt2, Stmt3 represent individual statements

statement( skip ) --> [skip].
statement( let( V, E ) ) --> [id( V )], [:=], expr( E ).
statement( if( C, Stmts ) ) -->
        [if], condition( C ), [then], statements( Stmts ), [fi].
statement( while( C, Stmts ) ) -->
        [while], condition( C ), [do], statements( Stmts ), [od].

condition( not( C ) ) --> [not], relation( C ).
condition( C ) --> relation( C ).

relation( cond( Op, E1, E2 ) ) --> expr( E1), comp_op( Op ), expr( E2 ).

comp_op( '=' ) --> ['='].
comp_op( '<' ) --> ['<'].

expr( E ) --> add_expr( AE ), rest_expr( AE, E ).

rest_expr( AE1, E ) -->
        ['+'], add_expr( AE2 ), rest_expr( e( '+', AE1, AE2 ), E ).
rest_expr( AE1, E ) -->
        ['-'], add_expr( AE2 ), rest_expr( e( '-', AE1, AE2 ), E ).
rest_expr( E, E ) --> [].

add_expr( AE ) --> mult_expr( ME ), rest_add_expr( ME, AE ).

rest_add_expr( ME1, AE ) -->
        ['*'], mult_expr( ME2 ), rest_add_expr( e( '*', ME1, ME2 ), AE ).
```

continued

```
rest_add_expr( ME1, AE ) -->
        ['/'], mult_expr( ME2 ), rest_add_expr( e( '/', ME1, ME2 ), AE ).
rest_add_expr( E, E ) --> [].

mult_expr( var( V ) ) --> [id( V )].
mult_expr( num( N ) ) --> [num( N )].
mult_expr( E ) --> ['('], expr( E ), [')'].

% === code generation ===
% statements
interm_code( s( Stmt, Stmts ) ) -->
        interm_code( Stmt ), interm_code( Stmts ).
interm_code( skip ) --> [].
interm_code( let( V, E ) ) -->
        expr_interm_code( E ), [store( V )].
interm_code( if( C, Stmts ) ) -->
        { newlabel( L ) },
        cond_interm_code( not( C ) ),
        [jmp_cond( L )],
        interm_code( Stmts ),
        [label( L )].
interm_code( while( C, Stmts ) ) -->
        { newlabel( L1 ) }, { newlabel( L2 ) },
        [label( L1 )],
        cond_interm_code( not( C ) ),
        [jmp_cond( L2 )],
        interm_code( Stmts ),
        [jmp( L1 )], [label( L2 )].

% conditions
cond_interm_code( not( not( C ) ) ) --> cond_interm_code( C ).
cond_interm_code( not( R ) ) -->
        rel_interm_code( R ), [flip].
                % flip: negate the contents of the condition register
cond_interm_code( R ) -->
        rel_interm_code( R ).

% relations
rel_interm_code( cond( Op, E1, E2 ) ) -->
        expr_interm_code( E2 ), { newmemloc( M ) }, [store( M )],
        expr_interm_code( E1 ), [sub( M )], tst_interm_code( Op ).

% set the condition register
tst_interm_code( '=' ) --> [tst_zer].
tst_interm_code( '<' ) --> [tst_neg].

% expressions
expr_interm_code( e( Op, E1, E2 ) ) -->
        expr_interm_code( E2 ), { newmemloc( M ) }, [store( M )],
        expr_interm_code( E1 ), eop_interm_code( Op, M ).
expr_interm_code( var( V ) ) -->
        [load( V )].
% load a constant
expr_interm_code( num( N ) ) -->
        [loadc( N )].

eop_interm_code( '+', M ) --> [add( M )].
eop_interm_code( '-', M ) --> [sub( M )].
eop_interm_code( '*', M ) --> [mul( M )].
eop_interm_code( '/', M ) --> [div( M )].

% auxiliaries
newlabel( L ) :-
        gensym( "$lbl", L ).
newmemloc( M ) :-
        gensym( "$mem", M ).

% === utilities ===
% symbol generator (preset in the main program)
set_gensym( Pref ) :-
        retract( sym( Pref, _ ) ), fail.
set_gensym( Pref ) :-
        assert( sym( Pref, 1 ) ).

gensym( Pref, Sym ) :-
       retract( sym( Pref, Num ) ),
```

```
        Num1 is Num + 1,
        assert( sym( Pref, Num1 ) ),
        glue( Pref, Num, Sym ).

glue( Pref, Num, Sym ) :-
        name( Num, Digits ), append( Pref, Digits, All ),
        name( Sym, All ), !.

% well, you can't have a program without append...
append( [], Z, Z ).
append( [A | X], Y, [A | Z] ) :- append( X, Y, Z ).

% end of program
```

DRAGON.BAS Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
1 '_____DRAGON PROGRAM_____
2 '
3 'This is the DRAGON.BAS program in Microsoft BASIC for the IBM PC and compatibles. If you have QuickBASIC, QDRAGON.BAS is
4 'easier to use and comes with quite a few dragon files (.CRV) that will make your fractal wanderings considerably easier.
5 'If you do not have that package, this program is fun and allows you to explore the dragons. It is not, however,
6 'forgiving of mistakes. Any data-entry mistakes require that you start over. Have a good time!
7 '
8 '
9 '
11 '
12 'To avoid local variables, I have replaced the loop index K with a one-dimensional array K, which holds the loop index
13 'at each level of recursion, and exchanged the variable CELL for a one-dimensional array CELL, which holds the cell
14 'value at each level of recursion. Since Microsoft BASIC does not permit subscripted variables to be FOR...NEXT loop
15 'indexes, I have replaced this loop with a WHILE...WEND block.
16 '
17 '
18 '
20 '----------Initialize
30 DATA 14,12,11,13,10,9,15
40 CLEAR,,10000
42 CLS
.RM63/46 FOR I=1 TO 7
48 READ X
49 NEXT I
50 '---------Get dragon
60 INPUT;"DRAGON FROM DISK (<CR> if no) ",C$:IF C$>"" THEN GOSUB 360:PRINT:GOTO 210
70 INPUT"NUMBER OF DIRECTIONS";D:INPUT"NUMBER OF CELLS (equal or greater the number of directions)";M:IF M<D THEN 70
80 INPUT"MAX NUMBER OF CELLS IN A CELL DIVISION";L:PRINT"Follow each input cell with <CR>":DIM G(M-1,L)
90 PRINT"cyclic? (<CR> if no)":IF INPUT$(1)=CHR$(13) THEN 140
100 J=0:WHILE J<M:PRINT"division of cell"J"(enter '.' after last cell of division less than"L:G(J,0)=L
110 FOR I=1 TO L:INPUT;" ",A$:G(J,I)=VAL(A$):IF INSTR(A$,".") THEN G(J,0)=I:I=L
120 NEXT I:PRINT:FOR I=1 TO G(J,0):S=G(J,I):T=S-(S MOD D):FOR K=J+1 TO J+D-1:G(K,0)=G(J,0):G(K,I)=((S+K) MOD D)+T:NEXT K,I
130 J=J+D:WEND:GOTO 170
140 FOR J=0 TO M-1:PRINT"DIVISION OF CELL"J"(enter (.) after last cell of divisions less than"L:G(J,0)=L
150 FOR I=1 TO L:INPUT;" ",A$:G(J,I)=VAL(A$):IF INSTR(A$,".") THEN G(J,0)=I:I=L
160 NEXT I:PRINT:NEXT J
170 DIM I(M-1):PRINT"If cell directions are CELL modulo NUMBER OF DIRECTIONS, then press <CR>":IF INPUT$(1)=CHR$(13) THEN FOR I=0
TO M-1:I(I)=I MOD D:NEXT I:GOTO 210
180 FOR I=0 TO M-1:PRINT"DIRECTION FOR CELL"I;:INPUT I$:IF I$="." THEN I(I)=-1 ELSE I(I)=VAL(I$)
190 NEXT I
200 '---------Compute direction vectors
210 T=6.28318531#/D:DIM X(D-1),XX(D-1),Y(D-1),YY(D-1):FOR I=0 TO D-1:XX(I)=COS(I*T):YY(I)=SIN(I*T):NEXT I
220 '--------Get drawing parameters
230 INPUT"NUMBER OF BIRTH CELLS IN START PATTERN ";T:PRINT"Follow each birth cell input with <CR>":DIM W(T-1):FOR I=0 TO
T-1:INPUT;" ", W(I):NEXT I:PRINT
240 INPUT;"AGE IN DAYS ",DAY:INPUT;" CELL LENGTH ",W:FOR I=0 TO D-1:X(I)=W*XX(I):Y(I)=W*YY(I):NEXT I:PRINT
250 INPUT;" COORDINATES OF HEAD CELL (",X:INPUT;",",Y:PRINT")":DIM K(DAY),CELL(DAY)
260 '--------Draw dragon and repeat
270 CLS
271 SCREEN 2
273 PRESET(X,Y)
275 FOR I=0 TO T-1
277 CELL(DAY)=W(I)
```

continued

```
278 GOSUB 310
279 NEXT I
280 PRINT"(1)NEW BIRTH CELL LIST, (2)NEW AGE, (3)SAVE TO DISK ":A$=INPUT$(1):ON INSTR("123",A$) GOTO 330,340,400
290 RUN
300 '--------Dragon procedure
310 IF DAY=0 THEN CODE=I(CELL(DAY)):GOSUB 450:RETURN
320 K(DAY)=1:WHILE K(DAY)<=G(CELL(DAY),0):CELL(DAY-1)=G(CELL(DAY),K(DAY)):DAY=DAY-1:GOSUB
310:DAY=DAY+1:K(DAY)=K(DAY)+1:WEND:RETURN
330 ERASE W,K,CELL:GOTO 230
340 ERASE K,CELL:GOTO 240
350 '--------Load dragon routine
360 OPEN"I",1,C$+".CRV":INPUT# 1,D,M,L:DIM G(M-1,L),I(M-1)
370 FOR I=0 TO M-1:INPUT# 1,G(I,0):FOR J=1 TO G(I,0):INPUT# 1,G(I,J):NEXT J,I
380 FOR I=0 TO M-1:INPUT# 1,I(I):NEXT I:CLOSE:RETURN
390 '--------Save dragon routine
400 INPUT"CURVE NAME";C$:OPEN "O",1,C$+".CRV"
410 PRINT# 1,D;M;L:FOR I=0 TO M-1:PRINT# 1,G(I,0);:FOR J=1 TO G(I,0)
420 PRINT# 1,G(I,J);:NEXT J:NEXT I:FOR I=0 TO M-1:PRINT# 1,I(I);:NEXT I
430 CLOSE:GOTO 280
440 '--------Routine to interpret a cell
450 IF CODE<0 THEN RETURN
460 IF CODE<D THEN X=X+X(CODE):Y=Y-Y(CODE):LINE-(X,Y),I MOD 7+1:RETURN
470 X=X+X(CODE-D):Y=Y-Y(CODE-D):PRESET(X,Y):RETURN
```

QRULES.TXT Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

Running QDRAGON

The new QDRAGON.BAS is written in QuickBASIC to exploit the DRAW commands and to make data entry less tedious. As I understand it, only the SCREEN commands must be changed to suit the graphics adapter available. The LINE commands have been replaced by DRAW commands to permit drawing cells that are more exotic than simple line segments. The default is a line segment drawn in a direction determined by the cell label number. The length of the line segment is determined by scale factor held in the "cell length" variable. If something else is desired, you must type in the appropriate sequence of DRAW commands. Such a sequence will be sized by the value in the "cell length" variable. The program displays the DRAW commands it will use.

QDRAGON.BAS improves on the user interface but is not yet ideal. It pretends it knows what you want as data and displays what it will use if you don't enter any data. Pressing Return repeatedly will show currently recorded data and how the program wants the data typed in. Pressing F1 at any time will draw the dragon determined by current data. The program always has complete data to draw some dragon. To enter data for a new dragon, simply enter the data requested followed by Return. To back up and change or view previously requested data, end entry with a].

The first thing the program wants to know is if you want a dragon stored on disk. Pressing Return or] ignores this request and displays the next, or previous, thing it wants. Otherwise you type in the name of a dragon stored on disk followed by Return or], or F1 if you want the program to draw the dragon you have named. Dragons stored on disk contain *all* the data required by the program, including positioning on the screen and the birth cell list. Hence loading a dragon from disk can be followed immediately by F1 which will draw it on the screen.

The next thing the program wants is the number of directions. This request is the number of cell orientations. Entering the number 4 means all cells are oriented in four directions, east, north, west, or south, as if reading a map. The program assumes that all cells are single line segments oriented in one of four directions unless told otherwise by you or the input file. In any case, the program will display the DRAW commands it will use. Entering the DRAW commands wanted (followed by Return,], or F1) changes the default value. Pressing] following data entry displays what the program thinks you typed.

Following the 'number of directions' request, QDRAGON.BAS wants the maximum cell division. This is so that the program can begin to dimension the genetic code array. You type in this value if it differs from the displayed value (Return cycles forward through data entry). The genetic code requires two dimensions, so if F1 is pressed now, all entries in the genetic code array will be zero, producing a dull dragon. The program redimensions the genetic code array whenever one of its dimensions is changed.

Next, the program wants the total number of cell types. This number completes the dimension of the genetic code array. The program displays, as always, what it thinks should be the number of cell types. Typing Return accepts the program's choice and displays what the program wants next and the value it will use if you don't change it.

After typing Return, the program displays the DRAW commands it will execute for the first cell. You should type Return to go on to the next program request, or type in the DRAW commands you want for the first cell followed by Return to advance to the next request or] to edit or preview the previous request. If you want a cell to be an invisible line segment, typing a dash will cause the program to record the appropriate DRAW commands, and if you want a 'do nothing' cell, typing * makes the program fill in DRAW commands that do the job.

Ending the entry with Return, the program will now exhibit the label of the first child of the first cell. Each cell divides into a number of cells, numbered from one to the number of cells into which the cell divides. A user entry here should be a cell label, a number between 0 and one less than the total number of cells. Typing Return causes the program to ask for the next child of the current cell. If the cell has fewer children than the maximum, the last child cell should be followed by a period.

Whenever the program asks you for the last child of a cell labelled a multiple of the number of directions, it permits you to end entry with an * to abort this feature. Without the * entry, the program will fill in child cells cyclically up to the next cell labelled a multiple of the number of directions and display the draw code for the next cell, which is a multiple of the number of directions.

After all cells and their children have been displayed, the program requests the number of cells in the birth cell list. Dragons can begin life as a single cell (number of cells in birth cell list, 1) or as several cells, each drawn in a different color. Next the dragon's age in days is requested. Following this comes a request for cell length and the position on the screen where drawing is to begin. The program draws the dragon starting at this position.

Finally, the program asks if the dragon just drawn is to be saved on disk. If so, you type a name of up to 8 letters followed by Return or]. Only Control-Break or illegal data entry ends the program.

QDRAGON.BAS displays DRAW commands instead of numbers, so ignore interpreter values in the table. The relation between interpreter values in the table and the draw codes in the program is I->TA360I/DR. Invisible cells end in BR and 'do nothing' cells end in NBR.

Have a good time exploring fractals. I have.

-William A. McWorter Jr.

QDRAGON.BAS Contributed by William A. McWorter Jr.
Accompanies "Programming Project: Creating Fractals" by William A. McWorter Jr. and Jane Morrill Tazelaar, August 1987, page 123.

```
' This program is QDRAGON.BAS, a QuickBASIC program for drawing fractals.
' Inputs to this program are the files with a .CRV suffix. Rules for running it are in QRULES.TXT.

d=4:l=2:m=4:w=1:s=10:n=5:x=320:y=175
dim i$(m-1),g(m,l),w(w):a=360/d
print"The program tries to anticipate your wishes."
print"You can cycle through the data for previewing"
print"or editing, or enter entirely new data."
print"<cr> cycles forward through data entry"
print"<]> cycles backwards through data entry."
print"<F1> at any time draws the dragon with current data."
print"But pressing it now will get you only an empty screen."
print"The backspace key allows erasing the last-typed character."
print

begin:print"input dragon? (<cr> or <]> if no) ";:t=pos(0)+1:gosub getcmd
if i$>" " then
open"I",#1,i$+".crv"
input#1,d,l,m:redim i$(m-1),g(m,l):a=360/d
for i=0 to m-1:input#1,i$(i):for j=0 to l:input#1,g(i,j):next j,i
input#1,w:redim w(w):for i=1 to w:input#1,w(i):next i
input#1,s,n,x,y:close
end if
if a$="]" then goto crvsave
if a$=chr$(0) then goto program
locate csrlin,pos(0),1

drctns: print"number of directions";
t=pos(0)+1:print d;:gosub getcmd
if i$>" " then d=val(i$):a=360/d
if a$=chr$(0) then goto program
if a$="]" then goto begin

dvsn: print"max cell division";
t=pos(0)+1:print l;:gosub getcmd
if i$>" " then l=val(i$):redim g(m-1,l),i$(m-1)
if a$=chr$(0) then goto program
if a$="]" then goto drctns
```

continued

```
cellno: print"number of cells";
t=pos(0)+1:print m;:gosub getcmd
if i$>" " then m=val(i$):redim g(m-1,1),i$(m-1)
if a$=chr$(0) then goto program
if a$="]" then goto dvsn
i=0:j=1

gnetic:if i$(i)=" " then i$(i)="TA"+str$((i mod d)*a)+"R"
if g(i,0)=0 then g(i,0)=1
drawcode: print"draw code for cell"i"is";
t=pos(0)+1:print" "i$(i)" <*> = 'do nothing'; <-> = 'invisible' ";
gosub getcmd
if i$>" " then
if instr(i$,"*") then i$(i)="TA"+str$((i mod d)*a)+"NBR":goto drawcode1
if instr(i$,"-") then i$(i)="TA"+str$((i mod d)*a)+"BR":goto drawcode1
i$(i)=i$
end if

drawcode1: if a$=chr$(0) then goto program
if a$="]" then
i=i-1:if i<0 then goto cellno else j=g(i,0):goto loop
end if

j=1
loop: print" cell"i"'s number"j"child is";
t=pos(0)+1:print g(i,j);
if j=g(i,0) then
if (i mod d)=0 then print" (end this entry with (*) to abort skip)";
end if
gosub getcmd
if i$>" " then
g(i,j)=val(i$):if instr(i$,".") then g(i,0)=j
end if
if a$=chr$(0) then goto program
if a$="]" then
if j=1 then goto gnetic
j=j-1:goto loop
end if
j=j+1:if j<=g(i,0) then goto loop
if (i mod d)<>0 then i=i+1:goto ilupend
if i+d<=m then
if i$=" " then i=i+1:goto ilupend
if instr(i$,"*") then i=i+1:goto ilupend
for u=i+1 to i+d-1
if i$(1)=" " then i$(u)=" ":goto 10
if instr(i$(i),"B") then i$(u)="TA"+str$((u mod d)*a)+"BR":goto 10
i$(u)="TA"+str$((u mod d)*a)+"R"
10 g(u,0)=g(i,0):for v=1 to g(i,0)
g(u,v)=g(i,v)-(g(i,v) mod d)+((g(i,v)+u) mod d)
next v,u:i=i+d:goto ilupend
end if
i=i+1
ilupend: if i<m then j=1:goto gnetic

initword:print"birth cell list length";
t=pos(0)+1:print w;:gosub getcmd
if i$>" " then w=val(i$):redim w(w):goto bcells
if a$=chr$(0) then goto program
if a$="]" then i=m-1:j=g(i,0):goto loop

bcells: i=1:print"cells"
loop1: print i"-th cell:";
t=pos(0)+1:print w(i);:gosub getcmd
if i$>" " then w(i)=val(i$)
if a$=chr$(0) then goto program
if a$="]" then if i=1 then goto initword else i=i-1:goto loop1
i=i+1:if i<=w then goto loop1

order:print"number of day's growth";:t=pos(0)+1:print n;:gosub getcmd
if i$>" " then n=val(i$)
if a$=chr$(0) then goto program
if a$="]" then i=w:goto bcells
```

```
length: print" cell length";
t=pos(0)+1:print s;:gosub getcmd
if i$>" " then s=val(i$)
if a$=chr$(0) then goto program
if a$="]" then goto order

xpos:print"x-origin";
t=pos(0)+1:print x;:gosub getcmd

if i$>" " then x=val(i$)
if a$=chr$(0) then goto program
if a$="]" then goto length

ypos:print"y-origin";
t=pos(0)+1:print y;:gosub getcmd
if i$>" " then y=val(i$)
if a$="]" then goto xpos
if a$=chr$(0) then goto program

crvsave: print"save name? (<cr> or <]> if no) ";:t=pos(0)+1:gosub getcmd
if i$="]" then goto ypos
if i$>" " then
open"O",1,i$+".crv"
print#1,d;l;m
for i=0 to m-1:print#1,i$(i):for j=0 to l:print#1,g(i,j);
next j:print#1,:next i
print#1,w;:for i=1 to w:print#1,w(i);:next i:print#1,
print#1,s;n;x;y:close
end if
if a$="]" then goto ypos
if a$=chr$(0) then goto program
goto begin

program:screen 2:cls:dim k(n),cell(n)
draw"BM="+varptr$(x)+",="+varptr$(y)
for i=2 to w+1:cell(n)=w(i-1):draw"C="+varptr$(i):gosub dragon:next i
erase k,cell:goto crvsave

dragon:
if n=0 then draw i$(cell(n))+str$(s):return
k(n)=1:while k(n)<=g(cell(n),0):cell(n-1)=g(cell(n),k(n)):n=n-1
gosub dragon:n=n+1:k(n)=k(n)+1:wend
return

getcmd:i$=" ":t0=pos(0)-1:locate csrlin,t,1
getcmd1: a$=" ":a$=input$(1)
if instr(chr$(13)+"]"+chr$(0),a$) then print:return
if a$=chr$(8) then
if pos(0)=t then goto getcmd1
i$=left$(i$,len(i$)-1):locate csrlin,pos(0)-1,1:goto getcmd1
end if
I$=I$+a$:print a$;
if len(i$)=1 then print string$(t0-t+2,32);:locate csrlin,t+1,1
goto getcmd1
```

INDEX.PAS Contributed by Dick Pountain. Accompanies "Focus on Algorithms: Search and Destroy," August 1987, page 257.

```
{ INDEX.PAS in Turbo Pascal 3.0 for IBM PC and compatibles }
{ A book indexing program -- requires an input file -- execute as .COM }
{ Also requires a Boring Words dictionary, BORING.DIC, in the .COM file's directory }
{ To execute .COM file, enter "index <inputfilename> <outputfilename> }
program INDEX;
const CR = #13;                                                    { carriage return character }
const maxDict = 3750;                        {maximum allowable dictionary entries}
type letters = 'a'..'z';
     wordtype= string[16];
     nodeptr = ^nodetype;
     nodetype= record
                info: wordtype;
```

continued

```
                next: nodeptr
               end;
var inputFile,outputFile: text;
    inputFilename, outputFilename: string[127];
    chr,firstletter: char;
    sortList: array[letters] of nodeptr;                    { the array of 26 lists }
    i: letters;
    word: wordtype;
    boringWords: array [1..maxDict] of wordtype;
    dictionary : text;
      endDict : integer;
procedure InitFiles;
begin                          { open input and output files }
  inputFilename := paramSTR(1);
  Assign(inputFile,inputFilename);
  Reset(inputFile);
  outputFilename := paramSTR(2);
  Assign(outputFile, outputFilename);
  Rewrite(outputFile);
end;
procedure GetWord(VAR infile: text; VAR word: wordtype);
begin                          { read a cleaned-up word from the input file }
  word := '';                                               { initialize to blank }
  repeat
    read(infile,chr);
    if chr in ['A'..'Z']                                    { convert all to lowercase }
    then chr := char(ord(chr)+32);
    if chr in ['a'..'z']                                    { only accept alpha characters }
    then word := word+chr;                                  { add to word being built }
  until (chr = ' ') or (chr = CR) or eof(infile)
end;
procedure Place(VAR list: nodeptr; word: wordtype);
var p,q,newnode: nodeptr;
    found: boolean;
begin                                   { insert new word into list in sorted position only if unique }
  q := nil;
  p := list;                                                { p points to head of list }
  found := false;
  while (p <> nil)                                          { not end of list and }
    and (not found)                                         { word not already here and }
    and (word >= p^.info) do                                { word alphabetically later than current }
    if p^.info = word                                       { does this node contain our word? }
    then found := true                                      { yes! word is already here }
    else begin
      q := p;                                               { remember this node and }
      p := p^.next                                          { move on to the next one }
    end; {while}
  if not found                                              { word isn't already here }
  then begin
    New(newnode);                                           { create a new node }
    newnode^.info := word;                                  { put word in its info field }
    if q = nil                                              { list was empty }
    then begin
      newnode^.next := list;                                { newnode becomes first }
      list := newnode
    end
    else begin
      newnode^.next := q^.next;                             { insert after node q }
      q^.next := newnode
    end
  end
end;
procedure SquirtOut(list: nodeptr; VAR outfile: text);
begin                          { send sorted list to output file }
  while list <> nil
  begin
    writeln(outfile,list^.info);
    list := list^.next
  end
end;
procedure ReadDictionary;
var i:integer;
begin
  Assign(dictionary,'BORING.DIC');
  Reset(dictionary);
  i := 1;
  repeat
```

```
    readln(dictionary,boringWords[i]);
    i := i + 1
    until eof(dictionary) or (i > maxDict);
  endDict := i;                                          {number of actual dictionary entries}
Close(dictionary)
end;
function Boring(word: wordtype): boolean;
var left,right,try,svleft,svright: integer;
begin
  left := 1;
  right := endDict;
  repeat
    svleft := left; svright := right;
    try := (left + right) div 2;
    if word < boringWords[try]
      then right := try - 1
      else left  := try + 1;
    until (word = boringWords[try]) or (svleft > svright) ;
if word = boringWords[try]
   then Boring := true
   else Boring := false
end;
begin                          { main program }
  InitFiles;
  ReadDictionary;
  for i := 'a' to 'z' do sortList[i] := nil;                    { initialize all the lists }
  while not eof(inputFile) do
  begin
    GetWord(inputFile,word);
    firstletter := word[1];                                     { get first letter }
    if not Boring(word)
      then Place(sortList[firstletter],word);                   { put word in proper place }
  end; {while}
  for i := 'a' to 'z' do SquirtOut(sortList[i],outputFile);
  writeln('Keywords are contained in ',outputFilename);
  Close(inputFile);
  Close(outputFile)
end.
```

OPS8085.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% Subject: OPS8085.ARI - from Alex Lane: "Simulating a Microprocessor"

comp_regs(Regname) :-
        retract(state(R,PC,SP,_)),
        reg(Regname,Place),
        arg(Place,R,Reg),
        X is A - Reg,
        adjust_flags(A,X,_,Flags),
        asserta(state(R,PC,SP,Flags)).

acc_math_with_carry(Op,Regname) :-
        retract(state(R,PC,SP,flags(_,_,_,CY,_))), % get what we need
        arg(1,R,A),                                % extract A from R
        reg(Regname,Place),     % Place is location of Regname in R
        arg(Place,R,Reg),       % extract register value
        T1 =.. [Op,Reg,CY],     % set up additions/subtractions
        T2 =.. [Op,A,T1],
        X is T2,                % evaluate
        adjust_flags(A,X,Y,Flags),  % adjust for flags
        argrep(R,1,Y,NewR),     % replace register value in R
        asserta(state(NewR,PC,SP,Flags)).

acc_math(Op,Regname) :-
        retract(state(R,PC,SP,_)),
        arg(1,R,A),
        reg(Regname,Place), arg(Place,R,Reg),
        T1 =.. [Op,A,Reg],
        X is T1,
```

continued

```
        adjust_flags(A,X,Y,Flags),
        argrep(R,1,Y,NewR),
        asserta(state(NewR,PC,SP,Flags)).

reg_math(Op,Regname) :-
        retract(state(R,PC,SP,flags(_,_,_,CY,_))), arg(1,R,A),
        reg(Regname,Place),     % Place is location of Regname in R
        arg(Place,R,Reg),       % extract register value
        T1 =.. [Op,Reg,TemReg],% take advantage of Arity inc( ) and dec( )
        call(T1),
        adjust_flags(A,TemReg,NewReg,flags1(Z,S,P,_,AC)),
        argrep(R,1,NewReg,NewR),      % replace register value in R
        asserta(state(NewR,PC,SP,flags(Z,S,P,CY,AC))).

not_implemented.    % some things are not worth doing.

undefined.

move(mem, mem).

move(mem,D) :-
        retract(state(R,PS,SP,F)),
        arg(6,R,H),
        arg(7,R,L),
        get_mem(H,L,Data),
        argrep(R,D,Data,NewR),
        asserta(state(NewR,PC,SP,F)).

move(S,mem) :-
        state(R,PS,SP,F),
        arg(6,R,H),
        arg(7,R,L),
        arg(S,R,Data),
        put_mem(H,L,Data).

move( S,D ) :-
        retract(state(R,P,SP,F)),
        arg(S,R,S1),
        argrep(R,D,S1,NewR),
        asserta(state(NewR,P,SP,F)).

reg_ptr(6,mem).
reg_ptr(A,B) :- B is (A + 2) mod 8.

op(0).                          /* NOP */

op(1) :-                        /* LXI BC */
        retract(state(regs(A,_,_,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,C), Hi is PC + 1,
        get_mem(Hi,B),
        NewPC is PC + 2,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(2) :-                        /* STAX B */
        state(regs(A,B,C,_,_,_,_),_,_,_),
        put_mem(B,C,A).

op(3) :-                        /* INX B */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        BC is 256 * B + C + 1,
        decompose(BC,NewB,NewC),
        asserta(state(regs(A,NewB,NewC,D,E,H,L),PC,SP,Flags)).

op(4) :-                        reg_math(inc,b),!.              /* INR B */

op(5) :-                        reg_math(dec,b),!.              /* DCR B */

op(6) :-                        /* MVI B, data */
        retract(state(regs(A,_,C,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,B),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).
```

```
op(7) :-                        /* RLC */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,_,AC))),
        CY is A mod 128,
        A1 is (2 * A + CY) mod 256,
        asserta(state(regs(A1,B,C,D,E,H,L),PC,SP,flags(Z,S,P,CY,AC))).

op(9) :-                        /* DAD B (CY only)*/
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,_,AC))),
        NewL is L + C,
        Carry is NewL // 256,
        NewH is H + B + Carry,
        CY is NewH // 256,
        FL is NewL /\ 255,
        FH is NewH /\ 255,
        asserta(state(regs(A,B,C,D,E,FH,FL),PC,SP,flags(Z,S,P,CY,AC))).

op(10) :-                       /* LDAX B */
        retract(state(regs(_,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(B,C,A),
        asserta(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)).

op(11) :-                       /* DCX B */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        BC is 256 * B + C - 1,
        decompose(BC,B1,C1),
        asserta(state(regs(A,B1,C1,D,E,H,L),PC,SP,Flags)).

op(12) :-                       reg_math(inc,c),!.              /* INR C */

op(13) :-                       reg_math(dec,c),!.              /* DCR C */

op(14) :-                       /* MVI C, data */
        retract(state(regs(A,B,_,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,C),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(15) :-                       /* RRC */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,_,AC))),
        CY is A mod 2,
        I1 is CY * 128,
        A1 is A // 2 + I1,
        asserta(state(regs(A1,B,C,D,E,H,L),PC,SP,flags(Z,S,P,CY,AC))).

op(17) :-                       /* LXI DE */
        retract(state(regs(A,B,C,_,_,H,L),PC,SP,Flags)),
        memory(PC,E),
        Hi is PC + 1,
        memory(Hi,D),
        NewPC is PC + 2,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(18) :-                       /* STAX D */
        state(regs(A,_,_,D,E,_,_),_,_,_),
        put_mem(D,E,A).

op(19) :-                       /* INX D */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        DE is 256 * D + E + 1,
        D1 is DE // 256,
        E1 is DE mod 256,
        asserta(state(regs(A,B,C,D1,E1,H,L),PC,SP,Flags)).

op(20) :-                       reg_math(inc,d),!.              /* INR D */

op(21) :-                       reg_math(dec,d),!.              /* DCR D */

op(22) :-                       /* MVI D, data */
        retract(state(regs(A,B,C,_,E,H,L),PC,SP,Flags)),
        memory(PC,D),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).
```

continued

```
op(23) :-                       /* RAL */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,CY,AC))),
        A1 is (2 * A + CY) mod 256,
        NewCY is A mod 128,
        asserta(state(regs(A1,B,C,D,E,H,L),PC,SP,flags(Z,S,P,NewCY,AC))).

op(25) :-                       /* DAD D */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,_,AC))),
        NewL is L + E,
        Carry is NewL // 256,
        NewH is H + D + Carry,
        CY is NewH // 256,
        FL is NewL /\ 255,
        FH is NewH /\ 255,
        asserta(state(regs(A,B,C,D,E,FH,FL),PC,SP,flags(Z,S,P,CY,AC))).

op(26) :-                       /* LDAX D */
        retract(state(regs(_,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(D,E,A),
        asserta(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)).

op(27) :-                       /* DCX D */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        DE is 256 * D + E - 1,
        decompose(DE,D1,E1),
        asserta(state(regs(A,B,C,D1,E1,H,L),PC,SP,Flags)).

op(28) :-                       reg_math(inc,e),!.              /* INR E */

op(29) :-                       reg_math(dec,e),!.              /* DCR E */

op(30) :-                       /* MVI E, data */
        retract(state(regs(A,B,C,D,_,H,L),PC,SP,Flags)),
        get_mem(PC,E),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(31) :-                       /* RAR */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,CY,AC))),
        A1 is (A // 2) + (128 * CY),
        NewCY is A mod 2,
        asserta(state(regs(A1,B,C,D,E,H,L),PC,SP,flags(Z,S,P,NewCY,AC))).

op(32) :-                       /* RIM (read interrupt mask) */
        not_implemented.

op(33) :-                       /* LXI HL */
        retract(state(regs(A,B,C,D,E,_,_),PC,SP,Flags)),
        get_mem(PC,L),
        H1 is PC + 1,
        get_mem(H1,H),
        NewPC is PC + 2,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(34) :-                       /* SHLD (store H L direct) */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,Lo),                 NextPC is PC + 1,
        get_mem(NextPC,H1),
        put_mem(H1,Lo,L),               NextLo is Lo + 1,
        put_mem(H1,NextLo,H),
        NewPC is PC + 2,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(35) :-                       /* INX H */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        HL is 256 * H + L + 1,
        decompose(HL,H1,L1),
        asserta(state(regs(A,B,C,D,E,H1,L1),PC,SP,Flags)).

op(36) :-                       reg_math(inc,h),!.              /* INR H */

op(37) :-                       reg_math(dec,h),!.              /* DCR H */
```

```
op(38) :-                       /* MVI H, data */
        retract(state(regs(A,B,C,D,E,_,L),PC,SP,Flags)),
        get_mem(PC,H),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(39) :-                       /* DAA */
        state(regs(A,B,C,D,E,H,L),_,_,flags(Z,S,P,CY,AC)),
        LSB is A /\ 15,
        LSB > 9;
        AC is 1, !, retract(state(_,PC,SP,F)),
        NewA is A + 6,
        asserta(state(regs(NewA,B,C,D,E,H,L),PC,SP,F)),
        MSB is NewA /\ 240,
        MSB > 9;
        CY is 1, !, retract(_,PC,_,_),
        FinalA is NewA + 6,
        asserta(state(regs(FinalA,B,C,D,E,H,L),PC,SP,F)).

op(41) :-                       /* DAD H */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,_,AC))),
        NewL is L + L,                  % sum L plus lo-order register
        Carry is NewL // 256,           % Carry is one if NewL > 255
        NewH is H + H + Carry,          % sum H with hi-order register
        CY is NewH // 256,              % CY flag is one if NewH > 255
        FL is NewL /\ 255,              % bring into byte range
        FH is NewH /\ 255,              % this one too
        asserta(state(regs(A,B,C,D,E,FH,FL),PC,SP,flags(Z,S,P,CY,AC))).

op(42) :-                       /* LHLD (load H L direct) */
        retract(state(regs(A,B,C,D,E,_,_),PC,SP,Flags)),
        get_mem(PC,Lo),                 NextPC is PC + 1,
        get_mem(NextPC,Hi),
        get_mem(Hi,Lo,L),               NextLo is Lo + 1,
        get_mem(Hi,NextLo,H),
        NewPC is PC + 2,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(43) :-                       /* DCX H */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        HL is 256 * H + L - 1,
        decompose(HL,H1,L1),
        asserta(state(regs(A,B,C,D,E,H1,L1),PC,SP,Flags)).

op(44) :-                       reg_math(inc,l),!.              /* INR L */

op(45) :-                       reg_math(dec,l),!.              /* DCR L */

op(46) :-                       /* MVI L, data */
        retract(state(regs(A,B,C,D,E,H,_),PC,SP,Flags)),
        get_mem(PC,L),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(47) :-                       /* CMA (complement accumulator) */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        bit_xor(A,255,NewA),
        asserta(state(regs(NewA,B,C,D,E,H,L),PC,SP,Flags)).

op(48) :-                       /* SIM (set interrupt mask) */
        not_implemented.

op(49) :-                       /* LXI SP */
        retract(state(Regs,PC,_,Flags)),
        get_mem(PC,SPL),
        Hi is PC + 1,
        get_mem(Hi,SPH),
        SP is 256 * SPH + SPL,
        NewPC is PC + 2,
        asserta(state(Regs,NewPC,SP,Flags)).
```

continued

```
op(50) :-                       /* STA Adr (store accumulator in address) */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,Lo),                 HiAdr is PC + 1,
        get_mem(HiAdr, Hi),
        put_mem(Hi,Lo,A),
        NewPC is PC + 2,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(51) :-                       /* INX SP */
        retract(state(Regs,PC,SP,Flags)),
        NewSP is SP + 1,
        check_overflow(NewSP,FinalSP),
        asserta(state(Regs,PC,FinalSP,Flags)).

op(52) :-                       /* INR M */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(_,_,_,CY,_))),
        get_mem(H,L,Data),
        NewData is Data + 1,
        adjust_flags(A,NewData,FinalData,flags1(Z,S,P,_,AC)),
        put_mem(H,L,FinalData),
        asserta(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,CY,AC))).

op(53) :-                       /* DCR M */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(_,_,_,CY,_))),
        get_mem(H,L,Data),
        NewData is Data - 1,
        adjust_flags(A,NewData,FinalData,flags1(Z,S,P,_,AC)),
        put_mem(H,L,FinalData),
        asserta(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,CY,AC))).

op(54) :-                       /* MVI M, data */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,Data),
        put_mem(H,L,Data),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(55) :-                       /* STC (set carry) */
        retract(state(Regs,PC,SP,flags(Z,S,P,_,AC))),
        asserta(state(Regs,PC,SP,flags(Z,S,P,1,AC))).

op(57) :-                       /* DAD SP */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,_,AC))),
        decompose(SP,SPH,SPL),
        NewL is L + SPL,
        Carry is NewL // 256,
        NewH is H + SPH + Carry,
        CY is NewH // 256,
        FL is NewL /\ 255,
        FH is NewH /\ 255,
        asserta(state(regs(A,B,C,D,E,FH,FL),PC,SP,flags(Z,S,P,CY,AC))).

op(58) :-                       /* LDA Adr */
        retract(state(regs(_,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,Lo),
        NextPC is PC + 1,
        get_mem(NextPC,Hi),
        get_mem(Hi,Lo,A),
        NewPC is PC + 2,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(59) :-                       /* DCX SP */
        retract(state(Registers,PC,SP,Flags)),
        NewSP is SP - 1,
        check_overflow(NewSP,FinalSP),
        asserta(state(Registers,PC,FinalSP,Flags)).

op(60) :-                       reg_math(inc,a),!.              /* INR A */

op(61) :-                       reg_math(dec,a),!.              /* DCR A */

op(62) :-                       /* MVI A, Data */
        retract(state(regs(_,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(PC,A),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).
```

```
op(63) :-                       /* CMC (complement carry) */
        retract(state(Regs,PC,SP,flags(Z,S,P,CY,AC))),
        bit_xor(1,CY,NewCY),
        asserta(state(Regs,PC,SP,flags(Z,S,P,NewCY,AC))).

op(Code) :-                     /* MOV Destination, Source */
        Code > 63, Code < 128,
        B210 is Code /\ 7,              % decode which reg is in bits 0-2
        B543 is (Code /\ 56) >> 3,      % do same for bits 3-5
        reg_ptr(B210,S),
        reg_ptr(B543,D),
        move(S,D).

op(128) :-          acc_math(+,b),!.

op(129) :-          acc_math(+,c),!.

op(130) :-          acc_math(+,d),!.

op(131) :-          acc_math(+,e),!.

op(132) :-          acc_math(+,h),!.

op(133) :-          acc_math(+,l),!.

op(134) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(H,L,Q),
        X is A + Q,
        adjust_flags(A,X,Y,Flags),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,Flags)).

op(135) :-          acc_math(+,a),!.

op(136) :-          acc_math_with_carry(+,b),!.         % add B with carry

op(137) :-          acc_math_with_carry(+,c),!.

op(138) :-          acc_math_with_carry(+,d),!.

op(139) :-          acc_math_with_carry(+,e),!.

op(140) :-          acc_math_with_carry(+,h),!.

op(141) :-          acc_math_with_carry(+,l),!.

op(142) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(H,L,Q),
        X is A + Q,
        adjust_flags(A,X,Y,Flags),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,Flags)).

op(143) :-          acc_math_with_carry(+,a),!.

op(144) :-          acc_math(-,b),!.

op(145) :-          acc_math(-,c),!.

op(146) :-          acc_math(-,d),!.

op(147) :-          acc_math(-,e),!.

op(148) :-          acc_math(-,h),!.

op(149) :-          acc_math(-,l),!.

op(150) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(H,L,Q),
        X is A + Q,
        adjust_flags(A,X,Y,Flags),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,Flags)).

op(151) :-          acc_math(-,a),!.
```

continued

```
op(152) :-          acc_math_with_carry(-,b),!.

op(153) :-          acc_math_with_carry(-,c),!.

op(154) :-          acc_math_with_carry(-,d),!.

op(155) :-          acc_math_with_carry(-,e),!.

op(156) :-          acc_math_with_carry(-,h),!.

op(157) :-          acc_math_with_carry(-,l),!.

op(158) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(_,_,_,CY,_))),
        get_mem(H,L,Q),
        X is A - Q - CY,
        adjust_flags(A,X,Y,Flags),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,Flags)).

op(159) :-          acc_math_with_carry(-,a),!.

op(160) :-          acc_math(/\,b),!.

op(161) :-          acc_math(/\,c),!.

op(162) :-          acc_math(/\,d),!.

op(163) :-          acc_math(/\,e),!.

op(164) :-          acc_math(/\,h),!.

op(165) :-          acc_math(/\,l),!.

op(166) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(H,L,M),
        X is A /\ M,
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,1))).

op(167) :-                  % AND A (affects flags)
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        adjust_flags(A,A,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,1))).

op(168) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        bit_xor(A,B,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(169) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        bit_xor(A,C,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(170) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        bit_xor(A,D,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(171) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        bit_xor(A,E,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(172) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        bit_xor(A,H,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).
```

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op(173) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        bit_xor(A,L,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(174) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(H,L,M),
        bit_xor(A,M,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(175) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        bit_xor(A,A,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(176) :-          acc_math(/\,b),!.

op(177) :-          acc_math(/\,c),!.

op(178) :-          acc_math(/\,d),!.

op(179) :-                  acc_math(/\,e),!.              /* ORA E */\

op(180) :-                  acc_math(/\,h),!.              /* ORA H */

op(181) :-                  acc_math(/\,l),!.

op(182) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(H,L,M),
        X is A /\ M,
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(183) :-
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        adjust_flags(A,A,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(184) :-          comp_regs(b),!.              /* CMP B */

op(185) :-          comp_regs(c),!.              /* CMP C */

op(186) :-          comp_regs(d),!.              /* CMP D */

op(187) :-          comp_regs(e),!.              /* CMP E */

op(188) :-          comp_regs(h),!.              /* CMP H */

op(189) :-          comp_regs(l),!.              /* CMP L */

op(190) :-                  /* CMP M */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(H,L,Q),
        X is A - Q,
        adjust_flags(A,X,_,Flags),
        asserta(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)).

op(191) :-                  /* CMP A */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        adjust_flags(A,0,_,Flags),
        asserta(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)).

op(192) :-                  /* RNZ */
        (not zero_flag_is_set, return); true.

op(193) :-                  /* POP B */
        retract(state(regs(A,_,_,D,E,H,L),PC,SP,Flags)),
        get_mem(SP,C),
        H1 is SP + 1,
        get_mem(H1,B),
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continued

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        NewSP is SP + 2,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,Flags)).

op(194) :-                      /* JNZ */
        (not zero_flag_is_set, jump); carry_on.

op(195) :-                      /* JMP */
        jump.

op(196) :-                      /* CNZ */
        (not zero_flag_is_set, call); carry_on.

op(197) :-                      /* PUSH B */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        Hi is SP - 1,
        put_mem(Hi,B),
        Lo is SP - 2,
        put_mem(Lo,C),
        NewSP is SP - 2,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,Flags)).

op(198) :-                      /* ADI D8 */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(PC,Q),
        X is A + Q,
        adjust_flags(A,X,Y,Flags),
        NewPC is PC + 1,
        asserta(state(regs(Y,B,C,D,E,H,L),NewPC,SP,Flags)).

op(199) :-                      /* RST 0 */
        reset(0).

op(200) :-                      /* RZ */
        (zero_flag_is_set, return); true.

op(201) :-                      /* RET */
        return.

op(202) :-                      /* JZ */
        (zero_flag_is_set, jump); carry_on.

op(204) :-                      /* CZ */
        (zero_flag_is_set, call); carry_on.

op(205) :-                      /* CALL */
        call.

op(206) :-                      /* ACI D8 */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(_,_,_,CY,_))),
        get_mem(PC,Q),
        X is A + Q + CY,
        adjust_flags(A,X,Y,Flags),
        NewPC is PC + 1,
        asserta(state(regs(Y,B,C,D,E,H,L),NewPC,SP,Flags)).

op(207) :-                      /* RST 1 */
        reset(1).

op(208) :-                      /* RNC */
        (not carry_flag_is_set, return); true.

op(209) :-                      /* POP D */
        retract(state(regs(A,B,C_,_,H,L),PC,SP,Flags)),
        get_mem(SP,E),
        Hi is SP + 1,
        get_mem(Hi,D),
        NewSP is SP + 2,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,Flags)).

op(210) :-                      /* JNC */
        (not carry_flag_is_set, jump); carry_on.

op(211) :-                      /* OUT */
        not_implemented.
```

```
op(212) :-                      /* CNC */
        (not carry_flag_is_set, call); carry_on.

op(213) :-                      /* PUSH D */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        Hi is SP - 1,
        put_mem(Hi,D),
        Lo is SP - 2,
        put_mem(Lo,E),
        NewSP is SP - 2,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,Flags)).

op(214) :-                      /* SUI D8 */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(PC,Q),
        X is A - Q,
        adjust_flags(A,X,Y,Flags),
        NewPC is PC + 1,
        asserta(state(regs(Y,B,C,D,E,H,L),NewPC,SP,Flags)).

op(215) :-                      /* RST 2 */
        reset(2).

op(216) :-                      /* RC */
        (carry_flag_is_set, return); true.

op(218) :-                      /* JC */
        (carry_flag_is_set, jump); carry_on.

op(219) :-                      /* IN */
        not_implemented.

op(220) :-                      /* CC */
        (carry_flag_is_set, call); carry_on.

op(222) :-                      /* SBI */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(_,_,_,CY,_))),
        get_mem(PC,Q),
        X is A - Q - CY,
        adjust_flags(A,X,Y,Flags),
        NewPC is PC + 1,
        asserta(state(regs(Y,B,C,D,E,H,L),NewPC,SP,Flags)).

op(223) :-                      /* RST 3 */
        reset(3).

op(224) :-                      /* RPO odd parity; flag is 0 */
        (not parity_flag_is_set, return); true.

op(225) :-                      /* POP H */
        retract(state(regs(A,B,C,D,E,_,_),PC,SP,Flags)),
        get_mem(SP,L),
        Hi is SP + 1,
        get_mem(Hi,H),
        NewSP is SP + 2,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,Flags)).

op(226) :-                      /* JPO odd parity; flag is 0 */
        (not parity_flag_is_set, jump); carry_on.

op(227) :-                      /* XTHL */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        get_mem(SP,NewH),
        put_mem(SP,H),
        SP1 is SP + 1,
        get_mem(SP1,NewL),
        put_mem(SP1,L),
        asserta(state(regs(A,B,C,D,E,NewH,NewL),PC,SP,Flags)).

op(228) :-                      /* CPO odd parity; flag is 0 */
        (not parity_flag_is_set, call); carry_on.

op(229) :-                      /* PUSH H */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        Hi is SP - 1,
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continued

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        put_mem(Hi,H),
        Lo is SP - 2,
        put_mem(Lo,L),
        NewSP is SP - 2,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,Flags)).

op(230) :-                      /* ANI D8 */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(PC,M),
        X is A /\ M,
        adjust_flags(A,X,Y,Flags),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,Flags)).

op(231) :-                      /* RST 4 */
        reset(4).

op(232) :-                      /* RPE odd parity; flag is 1 */
        (parity_flag_is_set, return); true.

op(233) :-                      /* PCHL */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        decompose(PC,PCH,PCL), % (i,o,o)
        decompose(NewPC,H,L),  % (o,i,i)
        asserta(state(regs(A,B,C,D,E,PCH,PCL),NewPC,SP,Flags)).

op(234) :-                      /* JPE odd parity; flag is 1 */
        (parity_flag_is_set, jump); carry_on.

op(235) :-                      /* XCHG */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)),
        asserta(state(regs(A,B,C,H,L,D,E),PC,SP,Flags)).

op(236) :-                      /* CPE odd parity; flag is 1 */
        (parity_flag_is_set, call); carry_on.

op(238) :-                      /* XRI D8 */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(PC,M),
        bit_xor(A,M,X),
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(239) :-                      /* RST 5 */
        reset(5).

op(240) :-                      /* RP sign flag is 0 */
        (not sign_flag_is_set, return); true.

op(241) :-                      /* POP PSW */
        retract(state(regs(_,B,C,D,E,H,L),PC,SP,_)),
        get_mem(SP,Flags),
        Hi is SP + 1,
        get_mem(Hi,A),
        NewSP is SP + 2,
        S is (Flags /\ 128) / 128,
        Z is (Flags /\ 64) / 64,
        AC is (Flags /\ 16) / 16,
        P is (Flags /\ 4) / 4,
        CY is Flags /\ 1,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,flags(Z,S,P,CY,AC))).

op(242) :-                      <* JP sign flag is 0 */
        (not sign_flag_is_set, jump); carry_on.

op(243) :-                      /* DI */
        not_implemented.

op(244) :-                      /* CP sign flag is 0 */
        (not sign_flag_is_set, call); carry_on.

op(245) :-                      /* PUSH PSW */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,flags(Z,S,P,CY,AC))),
        Hi is SP - 1,
        put_mem(Hi,A),
        Lo is SP - 2,
```

```
        Flags is CY * 1 + P * 4 + AC * 16 + Z * 64 + S * 128,
        put_mem(Lo,Flags),
        NewSP is SP - 2,
        asserta(state(regs(A,B,C,D,E,H,L),PC,NewSP,flags(Z,S,P,CY,AC))).

op(246) :-                      /* ORI D8 */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(PC,M),
        X is A /\ M,
        adjust_flags(A,X,Y,flags(Z,S,P,_,_)),
        asserta(state(regs(Y,B,C,D,E,H,L),PC,SP,flags(Z,S,P,0,0))).

op(247) :-                      /* RST 6 */
        reset(6).

op(248) :-                      /* RM sign flag is 1 */
        (sign_flag_is_set, return); true.

op(249) :-                      /* SPHL */
        retract(state(regs(A,B,C,D,E,H,L),PC,_,Flags)),
        decompose(SP,H,L),                  % (o,i,i)
        asserta(state(regs(A,B,C,D,E,H,L),PC,SP,Flags)).

op(250) :-                      /* JM sign flag is 1 */
        (sign_flag_is_set, jump); carry_on.

op(251) :-                      /* EI */
        not_implemented.

op(252) :-                      /* CM sign flag is 1 */
        (sign_flag_is_set, call); carry_on.

op(254) :-                      /* CPI D8 */
        retract(state(regs(A,B,C,D,E,H,L),PC,SP,_)),
        get_mem(PC,Q),
        X is A - Q,
        adjust_flags(A,X,Y,Flags),
        NewPC is PC + 1,
        asserta(state(regs(A,B,C,D,E,H,L),NewPC,SP,Flags)).

op(255) :-                      /* RST 7 */
        reset(7).

op(_) :- write('undefined opcode'), nl.

%
% end: OPS8085.ARI
```

HELP80.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% File: HELP80.ARI
%
%  "nondestructive" help - saves the screen while you access help info.
%
%  There's nothing here that can't be done with most Prolog implementations; here, we use Arity's region_ca/\3,
%  tget/2, and tmove/3 predicates to save the screen, save the cursor position, and restore the cursor position.
%  If your Prolog doesn't implement these features, they can be excised with no great harm done.
%
%  Arity/Prolog encloses strings within '$' characters, so this part may require some minor rewrite to work with other
%  Prolog implementations.
%
%

help :- grab(S,R,C),write($HELP

Commands can be entered as one or two unique letters ('t' for 'trace', 'sh'
for 'show'), or as complete words ('step').

All numbers input by the user are assumed to be base 16 (hexadecimal) numbers. This means, for example, that the
command 'step 10' is a request for 16 steps, not 10!
```

continued

```
Hexadecimal numbers that start with a letter must be typed in with a
leading zero (e.g., 'ff' must be typed in as '0ff').

Additional help is available for the following commands:

     status      change      trace      quit
     show        reset       step

To get additional help, type 'help' and the command word you are interested in.

$), let_go(S,R,C).

help(status) :- grab(S,R,C),write($STATUS

This command prints the state/4 clause to the screen. The information displayed by state/4 is not as "pretty" as that shown by
the 'show' command, but is complete.

$), let_go(S,R,C).

help(help) :- help.

help(show) :- grab(S,R,C),write($SHOW

Use this command to display the contents of a register, of a register-pair pointer, and of memory.

To display the contents of a register or of a register pair, type 'show' followed by the appropriate name.

If no parameters are supplied, 16 bytes of memory are shown starting at the current PC value. If only one memory address
is specified, only the contents of that address will be displayed.

Examples:
          show b                    Show contents of register b
          show bc                   Show contents of address pointed to by bc

          show                      Show contents of PC through PC + 16 (decimal)
          show 0020                 Show contents of address 0020
          show 0020 002f            Show contents of addresses 0020 through 002f

$), let_go(S,R,C).

help(change) :- grab(S,R,C),write($CHANGE

Use this command to change the contents of a register, of an address in memory, or of an address pointed to by a 16-bit register.

To change something, type 'change' followed by the appropriate register name or memory location, followed in turn by
the new value.

Examples:

          change 002c 3f            Changes the contents of address 002c to 3f
          change d 2c               Changes the contents of register d to 2c
          change pc 0f3             Changes the contents of the program counter to 0f3

$), let_go(S,R,C).

help(reset) :- grab(S,R,C),write($RESET

This command resets everything back to the initial state:

        state(regs(0,0,0,0,0,0,0,0),0,255,flags(0,0,0,0,0))

$), let_go(S,R,C).

help(step) :- grab(S,R,C),write($STEP

This command causes an instruction to be executed. Multiple instructions can be stepped by adding a second, numeric argument.

Examples:

          step                      Steps through one instruction
          step 3                    Steps through three instructions
          step 10                   Steps through 16 instructions

$), let_go(S,R,C).

help(my_trace) :- grab(S,R,C),write($TRACE
```

```
Like 'step', this command causes one instruction to be executed, but also displays the processor state upon completion.
Multiple traces can be performed by adding a second, numeric argument.

Examples:

          trace                    Steps through an instruction and shows all
          trace 3                  Steps and shows all through three instructions
          trace 10                 Steps and shows all through 16 instructions

$), let_go(S,R,C).

help(quit) :- grab(S,R,C),write($QUIT

This command brings you back to Prolog's '?-' prompt.

$), let_go(S,R,C).

%
%  grab/1 takes advantage of an Arity/Prolog predicate that reads characters and their attributes from the screen and places
%     them in a string. This in effect saves the screen while you are off getting help.
%
%  let_go/1 waits for the user to strike a key and then restores the screen to the way it looked before the help session.
%
%  if you don't mind losing the screen contents when you seek help, you can dispense with these predicates.
%

grab(S,R,C) :- tget(R,C),
               region_ca( (0,0), (24,79), S),
               cls, !.

let_go(S,R,C) :- write($Strike a key to continue ... $),
                 get0(Ch),
                 cls,
                 region_ca( (0,0), (24,79), S),
                 tmove(R,C), !.

% end
```

PREDS80.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% Subject: PREDS80.ARI - from Alex Lane: "Simulating a Microprocessor"

% bit_xor(A,B,C) :: C is exclusive-or of A and B
%

bit_xor(0,0,0) :- !.
bit_xor(0,1,1) :- !.
bit_xor(1,0,1) :- !.
bit_xor(1,1,0) :- !.
bit_xor(A,B,X) :-
        AA0 is A // 2,            A0 is A mod 2,
        BB0 is B // 2,            B0 is B mod 2,
        bit_xor(AA0,BB0,XX0),
        bit_xor(A0,B0,X0),
        X is 2 * XX0 + X0.

% adjust_flags( In, Out, flags(Z,S,P,CY,AC)) :: In --> Out and flags checked.
%

adjust_flags(A,In, Out, flags(Z,S,P,CY,AC)) :-
        check_carry( In, Out, CY ),
        check_zero(Out,Z),
        check_parity(Out,P),
        check_aux_carry(A,Out,AC),
        check_sign(Out,S).

% carry_on :: PC <-- PC + 2.
%
```

continued

```
carry_on :-
        retract(state(Regs,PC,SP,Flags)),
        NewPC is PC + 2,
        asserta(state(Regs,NewPC,SP,Flags)).

% check_zero(A,B) :: A == 0 --> B == 1, else B == 0.
%

check_zero(0,1) :- !.
check_zero(_,0).

% check_parity(X,Y) :: Y reflects odd parity of number of bits in X.

check_parity(X,Y) :- par(X,T), Y is T mod 2, !.

par(0,0) :- !.
par(1,1) :- !.
par(N,P) :- J is N mod 2,
            K is N // 2,
            par(K,P1),
            P is J + P1.

check_sign(X,1) :- X > 127, !.
check_sign(_,0).

check_carry(In,Out,1) :- In > 255, Out is In - 255, !.
check_carry(In,Out,1) :- In < 0, Out is In + 255, !.
check_carry(In, In,0).

check_aux_carry(OldAccum, NewAccum, 1) :-
        OldAccum /\ 24 =:= 8,          % old bit 3 on and old bit 4 off
        NewAccum /\ 24 =:= 16,!.       % new bit 4 on and new bit 3 off
                                % (=:= evaluates both sides and tests for equality)

check_aux_carry(_,_,0) :- !.

zero_flag_is_set :-
         state(_,_,_,flags(1,_,_,_,_)), !.

sign_flag_is_set :-
         state(_,_,_,flags(_,1,_,_,_)), !.

parity_flag_is_set :-
 pstate(_,_,_,flags(_,_,1,_,_)), !.

carry_flag_is_set :-
         state(_,_,_,flags(_,_,_,1,_)), !.

aux_carry_flag_is_set :-
         state(_,_,_,flags(_,_,_,_,1)), !.

% reset (N) :: store PC on stack, PC <-- 8 * N.
%

reset(N) :-
     retract(state(Registers,PC,SP,Flags)),
     decompose(PC,PCH,PCL),
     Hi is SP - 1,
     put_mem(Hi,PCH),
     NewSP is SP - 2,
     put_mem(NewSP,PCL),
     NewPC is 8 * N,
     asserta(state(Registers,NewPC,NewSP,Flags)).

% return :: pop PC off stack, adjust SP.
%

return :-
        retract(state(Registers,_,SP,Flags)),
        get_mem(SP,PCL),
        Hi is SP + 1,
        get_mem(Hi,PCH),
        PC is 256 * PCH + PCL,
        NewSP is SP + 2,
        asserta(state(Registers,PC,NewSP,Flags)).
```

```
jump :-
       retract(state(Registers,PC,SP,Flags)),
       get_mem(PC,PCL),
       Hi is PC + 1,
       get_mem(Hi,PCH),
       NewPC is 256 * PCH + PCL,
       asserta(state(Registers,NewPC,SP,Flags)).

call :-
       retract(state(Registers,PC,SP,Flags)),
       PCN is PC + 2,                  % here? or on return?
       PCH is PCN // 256,
       PCL is PCN mod 256,
       SP1 is SP - 1,
       SP2 is SP - 2,
       put_mem(SP1,PCH),
       put_mem(SP2,PCL),
       get_mem(PC,NPCL),
       Hi is PC + 1,
       get_mem(Hi,NPCH),
       NewPC is 256 * NPCH + NPCL,
       asserta(state(Registers,NewPC,SP2,Flags)).

% put_mem( H, L, Data) :: store Data in Address <-- 256 * H + L.
%

put_mem( Hi, Lo, NewData ) :-
        Address is 256 * Hi + Lo,
        put_mem(Address, NewData).

% put_mem( H, L, Data) :: store Data in Address.
%

put_mem(Address,NewData) :-
        retract(memory(Address,_)),
        asserta(memory(Address,NewData)).

% get_mem( H, L, Data) :: fetch Data in Address <-- 256 * H + L.
%

get_mem(Hi, Lo, Data ) :-
        Address is 256 * Hi + Lo,
        get_mem(Address,Data).

% get_mem( Address, Data) :: fetch Data in Address.
%

get_mem(Address, Data) :-
        memory(Address,Data).

% decompose(Address, Hibyte, Lobyte) :: Address <-- 256 * Hibyte + Lobyte
%   (o,i,i)
%

decompose(Address, Hibyte, Lobyte) :-  % (o,i,i)
        var(Address),                  % if Address is uninstantiated
        Address is 256 * Hibyte + Lobyte.

%  decompose(Address, Hibyte, Lobyte) :: Address --> Hibyte ; Lobyte
%    (i,o,o)
%

decompose(Address, Hibyte, Lobyte) :-  % (i,o,o)
        F is Address / 256,
        H is integer(F),
        Hibyte is H /\ 255,
        G is Address - 256 * H,
        Lobyte is integer(G).

put_address(Lo) :-                  % write an address in hex
     decompose(Lo,LoH,LoL),
     dec_hex_byte(LoH,LHH),
     dec_hex_byte(LoL,LLH),
     write(LHH),write(LLH),write(' : '),!.
```

continued

```
%  Decimal-to-hex and hex-to-decimal conversions.
%

dec_hex_byte( Dec, Hex ) :-          %(i,o)
     var(Hex),!,
     Dec < 256,
     Hi is Dec >> 4,
     Lo is Dec /\ 15,
     d_h(Hi,H),
     d_h(Lo,L),
     list_text([H,L],Hex).

dec_hex_byte( Dec, Hex ) :-          %(o,i)
     list_text([H,L],Hex),
     d_h(Hi,H),
     d_h(Lo,L),
     Dec is 16 * Hi + Lo,!.

d_h( In, Out ) :-          %(i,o)
     In < 10,
     Out is In + 48.

d_h( In, Out ) :-          %(i,o)
     Out is In + 55.

d_h( Out, In ) :-          %(o,i)
     In < 65,
     Out is In - 48.

d_h( Out, In ) :-          %(o,i)
     In < 71,
     Out is In - 55.

min(I1,I1,I2) :- I1 =< I2, !.
min(I2,I1,I2) :- I2 < I1.

for(X,X,X) :- !.
for(X,Y,X).
for(X,Y,Z) :- X1 is X + 1, for(X1,Y,Z).

append([H|T], L, [H|R]) :- !, append(T, L, R).
append([], L, L).

valid_adr(H,L) :- top_of_memory(TOM), TOM >= (256 * H + L).

reg(a,1).    reg(b,2).    reg(c,3).    reg(d,4).
reg(e,5).    reg(h,6).    reg(l,7).

fl(z,1).     fl(s,2).     fl(p,3).     fl(cy,4).    fl(ac,5).

%
% end: PREDS80.ARI
```

PARSE80.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% Subject: PARSE80.ARI - from Alex Lane: "Simulating a Microprocessor"

%  Use DCG to parse a command (request) from the simple monitor.
%
%  Intended to be used with TOKENS.ARI (5/10/86)
%
%  Basically want to implement following commands:
%                                                          Examples:
%
%  change --+-- memory-address ---- value                 (change 002c 3f)
%           +-- register-contents ---- value               (change d 2c)
%           +-- register-pair-pointer ---- value           (change pc 0f3)
%  help (a screen of help)                                 (help)
%  quit (back to DOS)                                      (quit)
%  reset (all parameters to some intial state)             (reset)
```

```
%  show --+-- register-contents                                    (show b)
%         +-- contents of register-pair-pointer                    (show bc)
%         +-- <memory, no range specified>                         (show)
%         +-- starting-memory-address                              (show 0020)
%         +-- starting-address --- ending-address                  (show 0020 002f)
%  step                                                            (step)
%  trace                                                           (trace)
%

parse_tokens(change(Adr,Val)) --> verb(change), address(Adr), byte(Val).

parse_tokens(change(Reg,Val)) --> verb(change), register_name(Reg), byte(Val).

parse_tokens(change(RegPair,Val)) --> verb(change), pointer(RegPair), byte(Val).

parse_tokens(change(Flag,Value)) --> verb(change), flag(Flag), flag_value(Value).

parse_tokens(show(Reg)) --> verb(show), register_name(Reg).

parse_tokens(show(Group)) --> verb(show), group_designation(Group).

parse_tokens(show(RegPair)) --> verb(show), pointer(RegPair).

parse_tokens(show(Start,End)) --> verb(show), address(Start), address(End),
                                  { Start =< End }.

parse_tokens(show(Start)) --> verb(show), address(Start).

parse_tokens(help(Topic)) --> verb(help), verb(Topic).

parse_tokens(step(Times)) --> verb(step), byte(Times).

parse_tokens(my_trace(Times)) --> verb(my_trace), byte(Times).

parse_tokens(Command) --> verb(Command), { Command \== change }.

address(Adr) --> [Adr], { Adr >= 0, top_of_memory(TOM), Adr =< TOM }.

byte(Val) --> [Val], { Val >= 0, Val < 256 }.

flag_value(X) --> [X], { X == 1; X == 0 }.

register_name(a) --> [a].   register_name(b) --> [b].
register_name(c) --> [c].   register_name(d) --> [d].
register_name(e) --> [e].   register_name(h) --> [h].
register_name(l) --> [l].   register_name(flags) --> [f];[fl];[flags].

flag(z) --> [z].   flag(s) --> [s].   flag(p) --> [p].
flag(cy) --> [cy]. flag(ac) --> [ac].

group_designation(all) --> [al];[all].
group_designation(regs) --> [r];[re];[regs].
group_designation(stack) --> [st];[stack].

pointer(bc) --> [bc].          pointer(de) --> [de].
pointer(pc) --> [p];[pc].      pointer(sp) --> [s];[sp].
pointer(hl) --> [hl];[m];[me];[mem].

verb(change) --> [c];[ch];[change];[set].   % 'set' is a synonym
verb(status) --> [state].                   % must say 'state'
verb(help) --> [h];[he];[help].
verb(quit) --> [q];[qu];[quit].
verb(show) --> [sh];[show].
verb(step) --> [st];[step].
verb(my_trace) --> [t];[tr];[trace].
verb(reset_processor) --> [r];[re];[reset].

% end PARSE80.ARI
```

continued

MON80.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% Subject: MON80.ARI - from Alex Lane: "Simulating a Microprocessor"

% state(_) needs to have been asserted.
% memory must be initialized (so we need 'memory')..



quit :- write('Quitting.'), nl, abort.

step :- step(1),!.

step(N) :- for(1,N,X), execute_instruction, N == X, !.

status :- state(R,P,S,F), write(state(R,P,S,F)), nl.

my_trace :- my_trace(1).

my_trace(N) :- for(1,N,X), execute_instruction, show(all), nl, N == X.

reset_processor :-
                retract(state(_,_,_,_)),
                asserta(state(regs(0,0,0,0,0,0,0,0),0,254,flags(0,0,0,0,0,0))).

change(Adr, Val) :-
                number(Adr),!,
                put_mem(Adr,Val).

change(Reg, Val) :-
                reg(Reg,X),!,
                retract(state(R,P,S,F)),
                argrep(R,X,Val,NewR),
                asserta(state(NewR,P,S,F)).

change(Flag, Val) :-
                fl(Flag,X),!,
                retract(state(R,P,S,F)),
                argrep(F,X,Val,NewF),
                asserta(state(R,P,S,NewF)).

change(pc, P) :-
                !, retract(state(R,_,S,F)),
                asserta(state(R,P,S,F)).

change(sp, S) :-
                !, retract(state(R,P,_,F)),
                asserta(state(R,P,S,F)).

change(bc, Val) :-
                !, state(R,_,_,_),
                arg(2,R,B),   arg(3,R,C),
                ifthen( valid_adr(B,C), put_mem(B,C,Val)).

change(de, Val) :-
                !, state(R,_,_,_),
                arg(4,R,D),   arg(5,R,E),
                ifthen( valid_adr(D,E), put_mem(D,E,Val)).

change(hl, Val) :-
                !, state(R,_,_,_),
                arg(6,R,H),   arg(7,R,L),
                ifthen( valid_adr(H,L), put_mem(H,L,Val)).

show(Reg) :-
                reg(Reg,X),
                state(R,_,_,_),
                arg(X,R,T), dec_hex_byte( T,HT),
                tab(1), concat([Reg,'(',HT,')'],Y),write(Y),!.
```

```
show(bc) :-
                state(R,_,_,_),
                arg(2,R,B),   arg(3,R,C),
                ifthenelse( valid_adr(B,C),
                            (get_mem(B,C,D), dec_hex_byte(D,DH)),
                            DH = $xx$),
                concat(['bc>',DH,'< '],Y),
                write(Y), !.

show(de) :-
                state(R,_,_,_),
                arg(4,R,D),   arg(5,R,E),
                ifthenelse( valid_adr(D,E),
                            (get_mem(D,E,D1), dec_hex_byte(D1,DH)),
                            DH = $xx$),
                concat(['de>',DH,'< '],Y),
                write(Y), !.

show(hl) :-
                state(R,_,_,_),
                arg(6,R,H),   arg(7,R,L),
                ifthenelse( valid_adr(H,L),
                            (get_mem(H,L,D), dec_hex_byte(D,DH)),
                            DH = $xx$),
                concat(['hl>',DH,'< '],Y),
                write(Y), !.

show(pc) :-
                state(_,P,_,_), dec_hex_byte(P,PH),
                concat(['pc>',PH,'< '],Y),
                write(Y), !.

show(sp) :-
                state(_,_,S,_), dec_hex_byte(S,SH),
                concat(['sp>',SH,'< '],Y),
                write(Y), !.

show(regs) :-   % show registers and pointers
                show(a), show(b), show(c), show(d), show(e), show(h), show(l),
                write(': '), show(bc), show(de), show(hl), show(pc), show(sp).

show(all) :-    % show registers, pointers, and flags
                show(regs),
                nl, show(flags).

show(flags) :- % show flags only.
                state(_,_,_,flags(Z,S,P,CY,AC)),
                write(' z = '),write(Z), write('; s = '), write(S),
                write('; p = '), write(P), write('; cy = '), write(CY),
                write('; ac = '), write(AC).

show(stack) :-
                state(_,_,S,_), S1 is S + 15,
                top_of_memory(TOM), min(S2,S1,TOM),
                show(S,S2).

show(Mem) :-    % show a single memory location's contents.
                show(Mem, Mem),!.

show :-         % starting with current PC address, show 16 bytes.
                state(_,P,_,_),
                top_of_memory(TOM), TOM_1 is TOM - 1,
                End is P + 15,   min(Q,TOM_1, End),
                show(P,Q),!.


show(Lo, Hi) :- % show specified memory range.
                number(Lo), number(Hi),
                Diff is Hi - Lo + 1,
                show_mem(Diff, Lo),!.

show_mem(0,_) :- !.
```

```
show_mem(Left, Start) :-
                min(X,16,Left),
                NewLeft is Left - X,
                put_address(Start),
                dec(X,XO),                          % because we are going to use zero indexing
                for(0,XO,Y),
                   [! Adr is Start + Y,
                   get_mem(Adr,Data),
                   dec_hex_byte(Data,DH),
                   write(DH),tab(1) !],
                XO == Y, nl, !,
                NewAdr is Start + X,
                show_mem(NewLeft,NewAdr).
%
% end: MON80.ARI
```

STARTUP.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 9: Standard startup source */

/* startup.c */

#ifdef HYPERC
/* Won't create window for us */
        stdTerm(PStr("Hyper-C window"));
    EXTERN CHAR getKey( );
#define getchar( ) getKey(TRUE)
#endif

#ifdef MPU68000
/* Aztec needs this */
pascal long TickCount( ) = 0xa975;
#endif


/* Start timing */
        long time;
        puts("Press any key to begin timed test: ");
        getchar( );
        puts("\nStarting\n");
        time = TickCount( );
```

MEMORY.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% File: MEMORY.ARI
%
% Note:
% Since this file is very repetitious, only a small portion of the
%   file is represented here.
% You can generate a complete copy of the file by running the
%   basic program MEMORY.BAS
%
%
%
% This file contains a predicate that initializes a 256-byte memory
%   (shades of the mid-70s!).
% To "run" a program on the simulated microprocessor, insert the
%   appropriate machine code bytes into the memory locations
%

init_mem :-
   asserta(top_of_memory(255)),
   assertz(memory(0,0)),     %  NOP
   assertz(memory(1,0)),     %  NOP
   assertz(memory(2,0)),     %  NOP
```

```
   assertz(memory(3,0)),     %  NOP
   assertz(memory(4,0)),     %  NOP
%  ...
   assertz(memory(253,0)),   %  NOP
   assertz(memory(254,0)),   %  NOP
   assertz(memory(255,0)).   %  NOP
%
% end
```

TOKENS80.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% Subject: TOKENS80.ARI - from Alex Lane: "Simulating a Microprocessor"

% This version of get_token_list(_) assumes all input numbers are in
% hexadecimal and delivers decimal numbers in the output; i.e.,
% entering 'show 0f' results in [show,15].

get_token_list(Result) :-                       % read a sentence from the terminal
                read_line(0,String),            % read a line of input from the console
                list_text([Char|Tail],String),
                tokenize([Char|Tail], [], Result).

tokenize([H|T],List,L) :-                       % if head of list starts with letter
                letter(H, Letter),!,
                restword(T,[Letter],Word,Rem),  % get the rest of a word
                append(List,[Word],Nlist),
                tokenize(Rem,Nlist,L).          % recurse, tokenize rest of list

tokenize([H|T], List, L) :-                     % if head of list starts with digit (0-9)
                digit(H),!,
                rest_num(T,[H],Num, Rem),       % get a number (Num will be decimal)
                append(List,[Num],Nlist),
                tokenize(Rem,Nlist,L).          % recurse, tokenize rest of list

tokenize([_|T], List, L) :-                     % if head of list is not letter or digit,
                !, tokenize(T,List,L).          % ignore it.

tokenize([],List,List).                         % stop recursion.

restword( [H|T], List, Word, X ) :-
                letter( H, Letter ),!,
                append( List, [Letter], Nlist ),
                restword( T, Nlist, Word, X ).

restword( [32|T], List, Word, T ) :-
                name( Word, List ),!.

restword( [_|T], List, Word, X ) :-
                !, restword( T, List, Word, X ).

restword( [], List, Word, [] ) :-
                !, name( Word, List ).

rest_num( [H|T], List, Num, X ) :-
                hexdigit( H,_) , !,             % rest of number may have 0-9, a-f
                append( List, [H], Nlist ),
                rest_num( T, Nlist, Num, X ).

rest_num( [32|T], List, Num, T ) :-             % space finishes number, go convert.
                cname( Num, List, 0 ),!.

rest_num( [],List,Num,[]) :-                    % nothing left, go convert.
                !, cname(Num, List, 0).

cname( F, [X|[]], N) :-                         % finished.
                !, hexdigit(X,Y), F is N + Y.
```

continued

```
cname( Number, [H|T] ,In ) :-                    % convert the input hex number to
                hexdigit(H,H1),                  % a decimal. User need never know!
                H2 is (In + H1) * 16,
                cname(Number, T, H2).            % recurse with shorter list in T

letter(C, C) :-
                C >= 97, C =< 122, !.            % 97 is "a", 122 is "z"
letter(C, D) :-
                C >= 65, C =< 90, !,             % 65 is "A", 90 is "Z"
                D is C + 32.                     % 32 is "a"-"A"

hexdigit(D,E) :-
                digit(D), E is D - 48.

hexdigit(D,F) :-
                letter(D,E), E >= 97, E =< 102,
                F is E - 87.

digit(C) :-
                C >= 48, C =< 57.                % 48 is "0", 57 is "9".

%
% end: TOKENS80.ARI
```

MEMORY.BAS Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
10 ' Program to create MEMORY.ARI file for Prolog program
20 '  for "Simulating a Microprocessor"
30 '  by Alex Lane
40 '
100 OPEN "MEMORY.ARI" FOR OUTPUT AS 1
110 PRINT#1, "% File: MEMORY.ARI"
120 PRINT#1, "%    from Simulating a Microprocessor by Alex Lane"
130 PRINT#1, "%"
140 PRINT#1, "% This file contains a predicate that initializes"
150 PRINT#1, "%    a 256-byte memory"
160 PRINT#1, "% To 'run' a program on the simulated microprocessor,
170 PRINT#1, "%    insert the appropriate machine code bytes into
180 PRINT#1, "%    the memory locations
190 PRINT#1, "%"
200 PRINT#1, "init_mem :-"
210 PRINT#1, "   asserta(top_of_memory(255)),"
220 FOR I = 0 TO 254
230 IS$ = STR$(I)
240 PRINT#1, "  assertz(memory("; IS$; ",0)),   % NOP"
250 NEXT I
260 PRINT#1, "  assertz(memory( 255,0)).   % NOP"
300 PRINT#1, "%"
310 PRINT#1, "% end"
320 CLOSE
400 END
```

INTERFACE.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 6: Interface benchmark */

#define HYPERC

/* interface.c */

/* Modified by Joel West, April 14, 1987 for all systems */

#include <stdio.h>
#ifdef HYPERC
#include <TBXTypes.h>
```

```
#include <events.h>
#else
#  ifdef MACC
#    include <macdefs.h>
#    include <events.h>
# else
#  ifdef AZTEC
#    include <window.h>
#    include <event.h>
#  else
#    ifdef LSC
#      include <EventMgr.h>
#    endif
#  endif
# endif
#endif

#define COUNT 10000

main()
{    int i, eMask1, eMask2, bool1, bool2;
  EventRecord eRcrd1, eRcrd2;

#include "startup.c"

   eMask1 = eMask2 = -1;
   for (i = 0; i < COUNT; ++i)
       {       bool1 = GetNextEvent(eMask1, &eRcrd1);
               bool2 = GetNextEvent(eMask2, &eRcrd2);

               bool1 = GetNextEvent(eMask1, &eRcrd1);
               bool2 = GetNextEvent(eMask2, &eRcrd2);

               bool1 = GetNextEvent(eMask1, &eRcrd1);
               bool2 = GetNextEvent(eMask2, &eRcrd2);

               bool1 = GetNextEvent(eMask1, &eRcrd1);
               bool2 = GetNextEvent(eMask2, &eRcrd2);
   }

#include "done.c"

}
```

START80.ARI Contributed by Alex Lane. Accompanies the article "Simulating a Microprocessor," August 1987, page 161.

```
% START80.ARI - from A. Lane: "Simulating an 8085 with Prolog"

% This file starts everything up.

go :-
   write('Loading memory.'),nl,
   consult(memory),
   write('Initializing memory.'),nl,
   init_mem,
   abolish(init_mem/0),
   write('Loading monitor.'), nl,
   consult(mon80),
   write('Loading command parser.'),nl,
   consult(parse80),
   write('Loading tokenizer.'), nl,
   consult(tokens80),
   write('Loading miscellaneous routines.'),nl,
   consult(preds80),
   write('Loading help information'),nl,
   consult(help80),
   write('Loading opcode predicates.'),nl,
   consult(ops8085),
   asserta(state(regs(0,0,0,0,0,0,0,0),0,255,flags(0,0,0,0,0))),
```

continued

```
   sign_on,
   monitor.

% op(_) :- write('instruction executed').

monitor :-
   repeat,
   prompt,
   get_token_list(Tokens),
   ifthenelse( parse_tokens(Command,Tokens,[]), % run command thru DCG. if valid
               call(Command) ,                  % do it, else
               write('invalid request') ),      % tell user no.
   fail.
execute_instruction :-
    retract(state(R,PC,SP,F)),
    NewPC is PC + 1,
    asserta(state(R,NewPC,SP,F)),
    get_mem(PC,Instruction),
    op(Instruction),!.

sign_on :-
   cls,
   write('8085 simulator'),nl,
   write($ Type 'h' for help.$), nl.

prompt :-
  tget(_,Col),            % find out what column cursor's in.
  ifthen( Col \= 0, nl),  % if cursor not in column 0, new line.
  write('-<'),!.          % print prompt.
%
% end START80.ARI
```

SIEVE.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 1: Sieve benchmark */

/* sieve.c */

#define LSC

/*      Eratosthenes Sieve prime number program from BYTE, January 1983

        Modified by Joel West, April 13, 1987, for 16-bit short
*/

#define REGISTER
#include <stdio.h>

#ifdef HYPERC
#include <TBXTypes.h>
#include <events.h>
#endif

#define TRUE    1
#define FALSE   0
#define size  8190

char flags [size + 1];

main()
{       REGISTER short i, prime, k, count, iter;

#include "startup.c"

        for (iter = 1; iter <= 10; iter++)                  /* do program 10 times */
        {           count = 0;                                  /* prime counter */
                    for (i = 0; i <= size; i++)                 /* set all flags true */
                              flags [i] = TRUE;

                    for (i = 0; i <= size; i++)
                    {         if (flags [i])                    /* found a prime */
```

```
                        {       prime = i + i + 3;                              /* twice index + 3 */
                                for (k = i + prime; k <= size; k+= prime) flags [k] = FALSE;    /* kill all multiple */
                                count++;                                        /* primes found */
                        }
                }
        }
#include "done.c"
}
```

SORT.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 4: Sort benchmark */


/* sort.c */

#define LSC

/*      sorting benchmark--calls randomly the number of times specified by MAXNUM to create an array of long integers, then does a
        quicksort on the array of longs. The program does this for the number of times specified by COUNT.

Modified by Joel West, April 13, 1987, for 16-bit short
*/

#include <stdio.h>

#ifdef HYPERC
#include <TBXTypes.h>
#include <events.h>
#endif

#define REGISTER

#define MAXNUM 1000
#define COUNT 10
#define MODULUS ((long) 0x20000)

#define C 13849L
#define A 25173L

long seed = 7L;
long random();
long buffer [MAXNUM] = {0};


main()
{           REGISTER short i, j;
            REGISTER long temp;

#include "startup.c"
            printf ("Filling array and sorting %d times\n", COUNT);
            for (i = 0; i < COUNT; ++i)
            {           for (j = 0; j < MAXNUM; ++j)
                                {       temp = random (MODULUS);
                                        if (temp < 0L)
                                            temp = (-temp);
                                        buffer[j] = temp;
                                }
                                printf ("Buffer full, iteration %d\n", i);
                                quick (0, MAXNUM - 1, buffer);
                        }

#include "done.c"
}


quick (lo, hi, base)
REGISTER short lo, hi;
```

continued

```
long base [];
{           REGISTER int i, j;
            REGISTER long pivot, temp;

            if (lo < hi)
            {           for (i = lo, j = hi-1, pivot = base [hi]; i < j; )
                        {       while (i < hi && base [i] <= pivot)
                                   ++i;
                                while (j > lo && base [j] >= pivot)
                                   --j;
                                if (i < j)
                                {    temp = base [i];
                                    base [i] = base [j];
                                    base [j] = temp;
                                }
                        }
                        temp = base [i];
                        base [i] = base [hi];
                        base [hi] = temp;
                        quick (lo, i - 1, base);
                        quick (i + 1, hi, base);
            }
}

long random (size)
REGISTER long size;
{
            seed = seed * A + C;
            return (seed % size);
}
```

SAVAGE.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 2: Savage benchmark */

/* savage.c */

#define LSC

/*
** savage.c -- floating-point speed and accuracy test. C version
** derived from BASIC version that appeared in Dr. Dobb's Journal,
** Sept. 1983, pp. 120-122.

Modified by Joel West, April 14, 1987

For accuracy on the Macintosh, we want to use the SANE 80-bit extended type for all compilers. This is:

          Lightspeed C  double
          Mac C         extended
          Hyper C       extended
          Aztec C       N/A
*/

#define ILOOP  2500
#include <stdio.h>

#ifdef MACC
#define EXTENDED extended
#include <sane.h>
#else
#ifdef HYPERC
#define EXTENDED extended
#include <TBXTypes.h>
#include <events.h>
#else
#define EXTENDED double
#endif
#endif
```

```
#ifdef HYPERC
#define log(x) ln(x)    /* wrong name. Others built in */
#else
#include <math.h>
#endif

main()
{       int i;
        EXTENDED a;

#include "startup.c"

1) a = 1.0;
   for (i = 1; i <= (ILOOP - 1); i++)
            a = tan(atan(exp(log(sqrt(a*a))))) + 1.0;

   printf("a = %20.14e\n", a);

#include "done.c"

}
```

FLOAT.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 7: Float benchmark */

#define LSC

/* float.c */

/* simple benchmark for testing floating-point speed of c libraries does repeated multiplications and divisions in a loop that is
   large enough to make the looping time insignificant */

#include <stdio.h>

#ifdef MACC
#define EXTENDED extended
#else
#ifdef HYPERC
#define EXTENDED extended
#include <TBXTypes.h>
#include <events.h>
#else
#define EXTENDED double
#endif
#endif

#define CONST1 3.141597E0
#define CONST2 1.7839032E4
#define COUNT 10000

main()
{       EXTENDED a, b, c;
        int i;

#include "startup.c"

        a = CONST1;
        b = CONST2;
        for (i = 0; i < COUNT; ++i)
        {       c = a * b;
                c = c / a;
                c = a * b;
                c = c / a;
                c = a * b;
                c = c / a;
                c = a * b;
                c = c / a;
                c = a * b;
```

continued

```
                c = c / a;
                c = a * b;
                c = c / a;
                c = a * b;
                c = c / a;
        }

#include "done.c"
}
```

DONE.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 10: standard termination header */

/* done.c */

/* End timing */
        time = TickCount( ) - time;
        printf("ticks=%ld\n",time);
        printf("Press any key to return to FINDER: ");
        getchar( );
```

FIB.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 5: Fib benchmark */

#define LSC

/* Fib.c */

/* Fibonacci benchmark, modified by Joel West, 4/13/87 */

#include <stdio.h>

#ifdef HYPERC
#include <TBXTypes.h>
#include <events.h>
#endif

#define REGISTER

#define NTIMES 10 /* number of times to compute Fibonacci value */
#define NUMBER 24 /* biggest one we can compute with 16 bits */


main()      /* compute Fibonacci value */
{           REGISTER short i;
            REGISTER unsigned short value;
            unsigned short fib();

#include "startup.c"

            for (i = 1; i <= NTIMES; i++)
               value = fib(NUMBER);

#include "done.c"

   exit(0);
}


unsigned short fib(x)     /* compute Fibonacci number recursively */
  REGISTER short x;
{           if (x > 2)
```

```
        return (fib(x - 1) + fib(x - 2));
    else
        return (1);
}
```

FILEIO.C Contributed by Joel West. Accompanies the review "Macintosh C Compilers Revisited," August 1987, page 219.

```
/* Listing 8: Fileio benchmark */

#define LSC

/* fileio.c */

/*      file reading and writing benchmark sequentially writes a 65,000-byte file on disk, generates random long numbers, and uses
        these modulo 65,000 to read and write strings of ODDNUM bytes with the file-handling system of the c package; the random-number
        generator is set to a specific seed, so that all compilers should generate the same code

   Fixed by Joel West, April 16, 1987, to use UNIX-standard creat()
   and open() parameters.
*/

#include <stdio.h>

#ifdef LSC
#include <unix.h>
#else
#ifndef MACC                    /* this is the right way to do it */
#include <fcntl.h>
#endif
#endif

#ifndef MACC
#define FILEMODE 0666           /* the normal rw-rw-rw */
#else
#define FILEMODE 0x7            /* Mac C only */
#define O_RDONLY 0
#define O_WRONLY 1
#define O_RDWR 2
#endif

#ifdef LSC
#define abort AbOrT             /* Lightspeed C has an 'abort' entry point */
#endif

#define ERROR -1
#define READERR 0
#define OKCLOSE 0

/* For lseek() */
#define BEG 0
#define CURR 1
#define END 2

#define FILESIZE 65000L
#define COUNT 500

#define C 13849L
#define A 25173L
#define ODDNUM 23

long seed = 7L;
long random (), lseek ();

main ()
{           int i;
            long j, pos;
            int fd;
            char buffer [ODDNUM + 1];
```

continued

```
#include "startup.c"

            if ((fd = creat ("test.dat", FILEMODE)) == ERROR)
              abort ("Can't create data file\n");
            else
              printf("File opened for sequential writing\n");

            for (j = 0; j < FILESIZE; ++j)
              if (write(fd, "x", 1) == ERROR)
               abort ("Unexpected EOF in writing data file\n");

            if (close (fd) != OKCLOSE)
              abort ("Error closing data file\n");
            else
              printf ("Normal termination writing data file\n");

            if ((fd = open ("test.dat", O_RDWR)) == ERROR)
              abort ("Can't open data file for random reading and writing\n");
            else
              printf ("File opened for random reading and writing\n");

            for (i = 0; i < COUNT; ++i)
            {         j = random (FILESIZE);
                      if (j < 0L)
                        j = (-j);
                      if (FILESIZE - j < ODDNUM)
                        continue;
                      if ((pos = lseek (fd, j, BEG)) == -1L)
                        abort ("Error reading at random offset\n");
                      if (read (fd, buffer, ODDNUM) == READERR)
                        abort ("Error reading at random offset\n");
                      j = random (FILESIZE);
                      if (j < 0L)
                        j = (-j);
                      if (FILESIZE - j < ODDNUM)
                        continue;
                      if ((pos = lseek (fd, j, BEG)) == -1L)
                        abort ("Error seeking to random offset\n");
                      if (write (fd, buffer, ODDNUM) == READERR)
                        abort ("Error writing at random offset\n");
            }
            if (close (fd) != OKCLOSE)
                      abort ("Error closing data file\n");
            else
                      printf ("Normal termination from random reading and writing\n");

#include "done.c"
}


long random (size)




long size;
{           seed = seed * A + C;
            return (seed % size);
}

abort (message)
char *message;
{           printf (message);
            exit (ERROR);
}
```

CHAOSBEN.BAS Contributed by Jerry Pournelle. Accompanies "Computing At Chaos Manor: Faster, Bigger, Better," August 1987, page 243.

The Benchmark Program

```
REM A benchmark program to test machines, compilers, and languages.
REM  **  DECLARATIONS

DEFINT I - N
DEFINT E
DEFDBL A - C
DEFDBL S
REM Variable "start$" is a string.

REM  ***   CONSTANTS

ELEMENTS = 50
SUM = 0
BELL$ = CHR$(7)

REM  ***  DIMENSIONS

DIM A(Elements, Elements)
DIM B(Elements, Elements)
DIM C(Elements, Elements)

REM  ***  PROGRAM

CLS                'Clear the screen or it'll scroll funny
Print "This is a program to fill two matrices of ";
print Elements;
print " elements, multiply them, and sum the result."
print
print "It can be used as a benchmark program to test ";
print "languages, compilers, or machines."
print
print "Written by Jerry Pournelle, May 1987."
print "Not copyrighted."

input "Start timer. Enter any character to begin. ";start$

GOSUB FillA
Print "A Filled."

GOSUB FillB
Print "B Filled"
GOSUB FillC   ' Needed because some compilers can't cope.
Print "C Filled"

GOSUB DoMultiply
Print "Multiplied"

GOSUB SumItUp
Print "Sum = ";Sum
BEEP (5)

END

REM *************  PROCEDURES  **********
FillA:
  FOR i = 1 to Elements
    FOR j = 1 to Elements
          A(i,j) = i + j
        NEXT
      NEXT
RETURN  ' End FillA
```

continued

```
FillB:
  FOR i = 1 to Elements
        FOR j = 1 to Elements
          B(i,j) = (i + j) / j
        NEXT
      NEXT
RETURN  'End FillB

FillC:
      FOR I = i = 1 to Elements
        FOR j = 1 to Elements
          C(i,j) = 0
        NEXT
      NEXT
RETURN  ' End FillC

DoMultiply:
      FOR i = 1 to Elements
        FOR j = 1 to Elements
          FOR k = 1 to Elements
            C(i,j) = C(i,j) + A(i,k) * B(k,j)
          NEXT
        NEXT
      NEXT
RETURN  ' End DoMultiply

SumItUp:
      FOR i = 1 to Elements
        FOR j = 1 to Elements
          SUM = SUM + C(i,j)
        NEXT
      NEXT
RETURN  ' End SumItUp

Print  "ESAD!"  ' Shouldn't be able to get here.
END
```

September

ALSPRO.TST Contributed by Alex Lane. From "ALS Prolog," BYTE, September 1987.

```
%
% "Translations" of Prolog benchmarks first used on Turbo Prolog.
%
% When running these benchmarks, remember that the read/1 predicate expects to see a period to signal the end of input!
%
% Note: All errors from the original set of benchmarks have been fixed.
%
%                                                    a.lane (4/17/87)
%
%-------------------------------------------------------------------------------------------------------------------------

%  Factorial Benchmark Test

fact :-
  write('Enter number of iterations '),
  read(Iter),nl,
  write('Enter factorial number '),
  read(Num),nl,nl,
  time(Start),
  repeat(Iter,Num),
  time(Finish),nl, Overall is Finish - Start,
  write('Time is '),write(Overall),nl.

  factorial(1,1) :- !.
  factorial(N,Result) :-
    N1 is N - 1,
    factorial(N1, Temporary),
    Result is N * Temporary.

  repeat(0,R) :- write(X),nl.
  repeat(N,R) :- factorial(R,_),
                 N1 is N - 1,
                 repeat(N1,R).

  time(Time) :- Time is cputime.

%-------------------------------------------------------------------------------------------------------------------------

%  List-Reversal Test Program

lrev :-
  write('Enter cycle length '),
  read(N),
  time(Start),
  cycle(N),
  time(Finish), Overall is Finish - Start,
  write('Time = '),write(Overall),nl.

append( [], L, L ).
append( [Z|L1], L2, [Z|L3] ) :- append( L1, L2, L3 ).

lips(L) :- rev([1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28,29,30,31,32,33,34,35,36,
37,38,39,40,41,42,43,44,45,46,47,48,49,50], L ).

lipshort(L) :- rev( [1,2,3,4,5,6,7,8,9,10], L ).

rev( [], [] ).
rev( [H|T], L ) :- rev( T,Z), append( Z, [H], L ).

cycle(0).
cycle(N) :- N1 is N - 1, lips(_), cycle(N1).

time(Time) :- Time is cputime.
```

continued

```
%-------------------------------------------------------------------------------------------------------------------------

%  Floating-Point Test Program

% This floating-point benchmark is significantly different from the one performed on Turbo Prolog.
%
% The heart of the Turbo benchmark reads:
%
%  calc(A,B) :-
%       C is 1.0,
%       C1 is C * A,
%       C2 is C1 * B,
%       C3 is C2 / A,
%       C  is C3 / B,
%       bound(C).
%
% which is flawed for two reasons. First, the value of C is reinitialized each time the predicate calc/2 is called, which defeats
% one of the reasons for performing these operations 5000 times: to see if there is any cumulative error. Second, the Turbo
% benchmark works only if the result of C3 / B is *exactly* 1.0. If there is any error (i.e., if, as is true with ALS Prolog,
% C3 / B is 1.00000000000000000001) the thing won't fly at all.

float :-
  time(Start),
  cycle(5000, 1.0, 2.71828, 3.14159 ),
  time(Finish), Overall is Finish - Start,
  write('Time is '),write(Overall),nl.

  calc(In,Out,A,B) :-
     C1 is In * A,
     C2 is C1 * B,
     C3 is C2 / A,
     Out is C3 / B.

  cycle(0,C,A,B) :-
    write('C is ',C),nl.

  cycle(N,C,A,B) :-
     calc(C,CF,A,B),
     N1 is N - 1,
     cycle(N1,CF,A,B).

time(Time) :- Time is cputime.

%-------------------------------------------------------------------------------------------------------------------------

%  Math Functions Test Program

goal :-
 write('Doing square root...'),nl,
 time(T1),
 cyclesqrt(1000,_,T1),
 write('Doing logs..'),nl,
 time(T2),
 cycleln(1000,_,T2),
 write('Doing exp..'),nl,
 time(T3),
 cycleexp(1000,_,T3),
 write('Doing atan..'),nl,
 time(T4),
 cycleatan(1000,_,T4),
 write('Doing sin...'),nl,
 time(T5),
 cyclesin(1000,_,T5).

cyclesqrt(0,R,T1) :- time(T6), Stime is T6 - T1,
                     write('SQRT : '),write(Stime),nl,!.

cyclesqrt(N, R, T) :-
    N > 0, N1 is N - 1, R is sqrt(100.0), cyclesqrt(N1,R,T).

cycleln(0,R,T2) :- time(T7), Ltime is T7 - T2,
                   write('LN : '),write(Ltime),nl.

cycleln(N, R,T) :-
    N > 0, N1 is N - 1, R is log(100.0), cycleln(N1,R,T).
```

```
cycleexp(0,R,T3) :- time(T8), Etime is T8 - T3,
                    write('EXP : '),write(Etime),nl.

cycleexp(N, R,T) :-
    N > 0, N1 is N - 1, R is exp(10.0), cycleexp(N1,R,T).

cycleatan(0,R,T4) :- time(T9), Atime is T9 - T4,
                     write('ATAN : '),write(Atime),nl.

cycleatan(N, R,T) :-
    N > 0, N1 is N - 1, R is atan(10.0), cycleatan(N1,R,T).

cyclesin(0,R,T5) :- time(T10), Stime is T10 - T5,
                    write('SIN : '),write(Stime),nl.

cyclesin(N, R,T) :-
    N > 0, N1 is N - 1, R is sin(10.0), cyclesin(N1,R,T).

time(Time) :- Time is cputime.

%-------------------------------------------------------------------------------------------------------------------------

%  Disk Read Program

dread :-
  see('a:tempo.dat'),
  time(Start),
  get_text(512),
  time(Finish), Overall is Finish - Start,
  seen, see(user),
  write('Time = '),write(Overall),nl,
  write('DONE'),nl.

get_text(0).
get_text(N) :-
     read(Str),
     N1 is N - 1,
     get_text(N1).

%-------------------------------------------------------------------------------------------------------------------------

%  Disk Write Benchmark

dwrite :-
  tell('a:tempo.dat'),
  time(Start),
  send_text(512),
  time(Finish), Overall is Finish - Start,
  told, tell(user),
  write('Time = '),write(Overall),nl,
  write('DONE'),nl.

send_text(0).
send_text(N) :-
     write('x234567812345678123456781234567012345678123456781234567812345670123456781234567812345678123456781234567.'),
     nl, N1 is N - 1,
     send_text(N1).

time(Time) :- Time is cputime.

%-------------------------------------------------------------------------------------------------------------------------

%  Tower of Hanoi Test Program

hanoi :-
  write('Enter tower height '),
  read(High),
  time(Start),
  hanoi(High),
  time(Finish), Overall is Finish - Start,
  write('Time : '),write(Overall),nl.

hanoi(N) :- move(N, left, center, right).
```

continued

```
move(0,_,_,_) :- !.
move(N, A, B, C) :-
     M is N - 1,
     move(M, A, C, B),
     move2(bottom, A, B),
     move(M, C, B, A).
move2(bottom, A, B) :-
     write('Move the disk on '),
     write(A),
     write(' to '),
     write(B),
     nl.

time(Time) :- Time is cputime.

%-------------------------------------------------------------------------------------------------------------------------

%  Sieve Test Program

eratosthenes :-
  time(Start),
  cycle(10),
  time(Finish), Overall is Finish - Start,
  write('Time is '),write(Overall),nl.

primes( Limit, Ps ) :-
        integers( 2, Limit, Is ),
        sift( Is, Ps ).

integers( Low, High, [Low|Rest] ) :-
        Low =< High, !, M is Low + 1,
        integers(M, High, Rest ).
integers( _,_,[] ).

sift( [], [] ).
sift( [I|Is], [I|Ps]) :-
       remove(I,Is,New),
       sift( New, Ps ).

remove(_,[],[]).
remove(P,[I|Is],[I|Nis]) :-
        I mod P =\= 0,!,
        remove(P, Is, Nis).
remove(P,[I|Is],Nis) :-
        I mod P =:= 0,
        remove(P, Is, Nis).

cycle(0).
cycle(N) :-
        N1 is N - 1,
        primes(100,_),
        cycle(N1).

time(Time) :- Time is cputime.

%-------------------------------------------------------------------------------------------------------------------------

%  This program is called with the query "?-boresea(X)."
%  X is the number of loop iterations executed. It should be big enough to give significant results.
%  suggested value for X: 100 for interpreted code
%                         1000 for compiled code
%  average values for C-prolog interpreter:
%        X=1000, Tloop=27.1   T.comp=1.0   Tnet=26.1   Klips=7.7

boresea(X)
     :- T1 is cputime,
        do_max_KLips(X),                % calls the loop to execute the
        T2 is cputime,                  % sequence of 200 predicates
        compens_loop(X),                % compensation loop
        T3 is cputime,
        print_times(T1,T2,T3,X,200).    % compute and print results

compens_loop(0).                                % compensation loop
compens_loop(X) :- Y is X - 1, compens_loop(Y).
```

```
print_times(T1,T2,T3,X,I) :-                    % prints the results
        TT1 is T2 - T1,
        TT2 is T3 - T2,
        TT is TT1 - TT2,
        write('T overall loop:              '),write(TT1), nl,
        write('T compens loop:              '),write(TT2), nl,
        write('T net:                       '),write(TT),nl,
        write('KLips:                       '),
        Li is I * X,
        Lips is Li / TT,
        KLips is Lips / 1000,
        write(KLips),nl,nl.

do_max_KLips(0).                                % loop calling the actual benchmark
do_max_KLips(X) :- lips1, Y is X - 1, do_max_KLips(Y).

%  predicates to test call

lips1 :- lips2.
lips2 :- lips3.
lips3 :- lips4.
lips4 :- lips5.
lips5 :- lips6.
lips6 :- lips7.
lips7 :- lips8.
lips8 :- lips9.
lips9 :- lips10.
lips10 :- lips11.
lips11 :- lips12.
lips12 :- lips13.
lips13 :- lips14.
lips14 :- lips15.
lips15 :- lips16.
lips16 :- lips17.
lips17 :- lips18.
lips18 :- lips19.
lips19 :- lips20.
lips20 :- lips21.
lips21 :- lips22.
lips22 :- lips23.
lips23 :- lips24.
lips24 :- lips25.
lips25 :- lips26.
lips26 :- lips27.
lips27 :- lips28.
lips28 :- lips29.
lips29 :- lips30.
lips30 :- lips31.
lips31 :- lips32.
lips32 :- lips33.
lips33 :- lips34.
lips34 :- lips35.
lips35 :- lips36.
lips36 :- lips37.
lips37 :- lips38.
lips38 :- lips39.
lips39 :- lips40.
lips40 :- lips41.
lips41 :- lips42.
lips42 :- lips43.
lips43 :- lips44.
lips44 :- lips45.
lips45 :- lips46.
lips46 :- lips47.
lips47 :- lips48.
lips48 :- lips49.
lips49 :- lips50.
lips50 :- lips51.
lips51 :- lips52.
lips52 :- lips53.
lips53 :- lips54.
lips54 :- lips55.
lips55 :- lips56.
lips56 :- lips57.
lips57 :- lips58.
```

continued

```
lips58 :- lips59.
lips59 :- lips60.
lips60 :- lips61.
lips61 :- lips62.
lips62 :- lips63.
lips63 :- lips64.
lips64 :- lips65.
lips65 :- lips66.
lips66 :- lips67.
lips67 :- lips68.
lips68 :- lips69.
lips69 :- lips70.
lips70 :- lips71.
lips71 :- lips72.
lips72 :- lips73.
lips73 :- lips74.
lips74 :- lips75.
lips75 :- lips76.
lips76 :- lips77.
lips77 :- lips78.
lips78 :- lips79.
lips79 :- lips80.
lips80 :- lips81.
lips81 :- lips82.
lips82 :- lips83.
lips83 :- lips84.
lips84 :- lips85.
lips85 :- lips86.
lips86 :- lips87.
lips87 :- lips88.
lips88 :- lips89.
lips89 :- lips90.
lips90 :- lips91.
lips91 :- lips92.
lips92 :- lips93.
lips93 :- lips94.
lips94 :- lips95.
lips95 :- lips96.
lips96 :- lips97.
lips97 :- lips98.
lips98 :- lips99.
lips99 :- lips100.
lips100 :- lips101.
lips101 :- lips102.
lips102 :- lips103.
lips103 :- lips104.
lips104 :- lips105.
lips105 :- lips106.
lips106 :- lips107.
lips107 :- lips108.
lips108 :- lips109.
lips109 :- lips110.
lips110 :- lips111.
lips111 :- lips112.
lips112 :- lips113.
lips113 :- lips114.
lips114 :- lips115.
lips115 :- lips116.
lips116 :- lips117.
lips117 :- lips118.
lips118 :- lips119.
lips119 :- lips120.
lips120 :- lips121.
lips121 :- lips122.
lips122 :- lips123.
lips123 :- lips124.
lips124 :- lips125.
lips125 :- lips126.
lips126 :- lips127.
lips127 :- lips128.
lips128 :- lips129.
lips129 :- lips130.
lips130 :- lips131.
lips131 :- lips132.
lips132 :- lips133.
lips133 :- lips134.
```

```
lips134 :- lips135.
lips135 :- lips136.
lips136 :- lips137.
lips137 :- lips138.
lips138 :- lips139.
lips139 :- lips140.
lips140 :- lips141.
lips141 :- lips142.
lips142 :- lips143.
lips143 :- lips144.
lips144 :- lips145.
lips145 :- lips146.
lips146 :- lips147.
lips147 :- lips148.
lips148 :- lips149.
lips149 :- lips150.
lips150 :- lips151.
lips151 :- lips152.
lips152 :- lips153.
lips153 :- lips154.
lips154 :- lips155.
lips155 :- lips156.
lips156 :- lips157.
lips157 :- lips158.
lips158 :- lips159.
lips159 :- lips160.
lips160 :- lips161.
lips161 :- lips162.
lips162 :- lips163.
lips163 :- lips164.
lips164 :- lips165.
lips165 :- lips166.
lips166 :- lips167.
lips167 :- lips168.
lips168 :- lips169.
lips169 :- lips170.
lips170 :- lips171.
lips171 :- lips172.
lips172 :- lips173.
lips173 :- lips174.
lips174 :- lips175.
lips175 :- lips176.
lips176 :- lips177.
lips177 :- lips178.
lips178 :- lips179.
lips179 :- lips180.
lips180 :- lips181.
lips181 :- lips182.
lips182 :- lips183.
lips183 :- lips184.
lips184 :- lips185.
lips185 :- lips186.
lips186 :- lips187.
lips187 :- lips188.
lips188 :- lips189.
lips189 :- lips190.
lips190 :- lips191.
lips191 :- lips192.
lips192 :- lips193.
lips193 :- lips194.
lips194 :- lips195.
lips195 :- lips196.
lips196 :- lips197.
lips197 :- lips198.
lips198 :- lips199.
lips199 :- lips200.
lips200.

%-----------------------------------------------------------------------------------------------------------------------
% Choice Point Benchmark.

% The predicates are called:
%  o "choice_point(N)"          - creation of choice points
% N is the number of loop iterations executed
```

continued

```
% predicate to test creation of choice points without
% backtracking

choice_point(N) :- T1 is cputime,
        cre_CP(N), T2 is cputime,
        compens_loop(N), T3 is cputime,
        print_times(T1,T2,T3,N,20).

% compensation loop, used to measure the time spent in
% the loop

compens_loop(0).
compens_loop(X) :- Y is X - 1, compens_loop(Y).

% loop to test choice point creation

cre_CP(0).
cre_CP(N):-M is N-1, ccp1(0,0,0), cre_CP(M).

cre_CP0ar(0).
cre_CP0ar(N):-M is N-1, ccp1, cre_CP0ar(M).

print_times(T1,T2,T3,X,I) :-                % prints the results
        TT1 is T2 - T1,
        TT2 is T3 - T2,
        TT is TT1 - TT2,
        write('T overall loop:              '),write(TT1), nl,
        write('T compens loop:              '),write(TT2), nl,
        write('T net:                       '),write(TT),nl,
        write('KLips:                       '),
        Li is I * X,
        Lips is Li / TT,
        KLips is Lips / 1000,
        write(KLips),nl,nl.

% ccp1 creates 20 choice points
% ccp1 is the beginning of a set of predicates composed of 2 clauses each. Every invocation of nd0 will create
% a sequence of 20 choice points. The body of the clauses are limited to one goal, thus avoiding a creation of environment
% when the clause is activated. nd0, and its successors, have three arguments to comply with our average static analysis
% results made on more than 30 real Prolog programs.
% ccpXX exists with 3 arguments, and 0 args.

ccp1(X,Y,Z):-ccp2(X,Y,Z).
ccp1(X,Y,Z).
ccp2(X,Y,Z):-ccp3(X,Y,Z).
ccp2(X,Y,Z).
ccp3(X,Y,Z):-ccp4(X,Y,Z).
ccp3(X,Y,Z).
ccp4(X,Y,Z):-ccp5(X,Y,Z).
ccp4(X,Y,Z).
ccp5(X,Y,Z):-ccp6(X,Y,Z).
ccp5(X,Y,Z).
ccp6(X,Y,Z):-ccp7(X,Y,Z).
ccp6(X,Y,Z).
ccp7(X,Y,Z):-ccp8(X,Y,Z).
ccp7(X,Y,Z).
ccp8(X,Y,Z):-ccp9(X,Y,Z).
ccp8(X,Y,Z).
ccp9(X,Y,Z):-ccp10(X,Y,Z).
ccp9(X,Y,Z).
ccp10(X,Y,Z):-ccp11(X,Y,Z).
ccp10(X,Y,Z).
ccp11(X,Y,Z):-ccp12(X,Y,Z).
ccp11(X,Y,Z).
ccp12(X,Y,Z):-ccp13(X,Y,Z).
ccp12(X,Y,Z).
ccp13(X,Y,Z):-ccp14(X,Y,Z).
ccp13(X,Y,Z).
ccp14(X,Y,Z):-ccp15(X,Y,Z).
ccp14(X,Y,Z).
ccp15(X,Y,Z):-ccp16(X,Y,Z).
ccp15(X,Y,Z).
ccp16(X,Y,Z):-ccp17(X,Y,Z).
ccp16(X,Y,Z).
ccp17(X,Y,Z):-ccp18(X,Y,Z).
ccp17(X,Y,Z).
```

```
ccp18(X,Y,Z):-ccp19(X,Y,Z).
ccp18(X,Y,Z).
ccp19(X,Y,Z):-ccp20(X,Y,Z).
ccp19(X,Y,Z).
ccp20(X,Y,Z).
ccp20(X,Y,Z).
```

KAREX3.BAS Accompanies the article "Karmarkar's Algorithm" by Andrew M. Rockett and John C. Stevenson, BYTE, September 1987.

```
100 '-------------------------------------------------------
101 '
102 '      KAREX3.BAS is a Microsoft BASIC Release 5 program
103 '             that solves EXAMPLE 3 of the article
104 '
105 '                      KARMARKAR'S ALGORITHM
106 '
107 '          by Andrew M. Rockett and John C. Stevenson
108 '
109 '        This program was written by Andrew M. Rockett
110 '
111 '-------------------------------------------------------
200 '
202 ' N is the number of unknowns and K is the number of equations
204 '
206 N = 8 : K = 4
208 '
210 K1 = K + 1 : K2 = 2*K1
212 DIM AO(N), XOLD(N), XNEW(N), CC(N), CP(N), A(K,N), B(K1,N), B1(K1,K2), B2(N,K1), B3(N,N)
214 FOR C = 1 TO N : AO(C) = 1/N : XNEW(C) = AO(C) :
     NEXT C
216 '
218 ' T is the tolerance
220 '
222 T = .001
224 '
226 ' ALPHA is usually set equal to 1/4 ...
228 '
230 ALPHA = .25
232 '
234 ITERATION = 0
236 '
238 ' Data for constraint matrix A
240 '
242 DATA 1, 0, -1, 0, 0, 0, 3, -3
244 DATA 1, 0, 0, 1, 0, 0, 0, -2
246 DATA 0, 1, 0, 0, 1, 0, 3, -5
248 DATA 0, 1, 0, 0, 0, -1, 4, -4
250 '
252 FOR R = 1 TO K : FOR C = 1 TO N : READ A(R,C) :
     NEXT C : NEXT R
254 '
256 ' Data for objective function CC
258 '
260 DATA 0, 0, 0, 0, 0, 0, 1, 0
262 '
264 FOR C = 1 TO N : READ CC(C) : NEXT C
266 '
268 V = 0 : FOR C=1 TO N : V = V + CC(C)*AO(C) :
      NEXT C : VNEW = V
270 '
272 ' Main iteration process is the same as in KAREX1.BAS ...
274 '
300 WHILE VNEW/V > T
301 PRINT USING "###";ITERATION;:
     FOR C=1 TO N:PRINT USING "###.####";XNEW(C); :
     NEXT C :PRINT USING "####.#######";VNEW/V
302 ITERATION = ITERATION + 1
303 FOR C = 1 TO N : XOLD(C) = XNEW(C) : NEXT C
```

continued

```
304 FOR R=1 TO K:FOR C=1 TO N:B(R,C)=A(R,C)*XOLD(C):
    NEXT C:NEXT R
305 FOR C=1 TO N:B(K1,C)=1:NEXT C
306 FOR R=1 TO K1 : FOR C=1 TO K2 : B1(R,C)=0 :
    NEXT C : NEXT R
307 FOR R=1 TO N : FOR C=1 TO K1 : B2(R,C)=0 :
    NEXT C : NEXT R
308 FOR R=1 TO N : FOR C=1 TO N : B3(R,C)=0 :
    NEXT C : NEXT R
309 FOR C=1 TO N : CP(C) = 0 : NEXT C
310 FOR R=1 TO K1:FOR C=1 TO K1:
      FOR I=1 TO N:B1(R,C)=B1(R,C)+B(R,I)*B(C,I):
       NEXT I:
    NEXT C:NEXT R
311 FOR I = 1 TO K1 : B1(I,I+K1)=1 : NEXT I
312 FOR R = 1 TO K1
313   IF B1(R,R) <> 0 THEN 318
314     I = R + 1
315     IF I > K1 THEN PRINT "Error! BBT is SINGULAR!" :
        GOTO 405
316     IF B1(I,R) = 0 THEN I = I+1 : GOTO 315
317     FOR C = 1 TO K2 : SWAP B1(R,C),B1(I,C) : NEXT C
318 FOR I = R+1 TO K1:Z = B1(I,R)/B1(R,R):
      FOR C=1 TO K2:B1(I,C)=B1(I,C)-Z*B1(R,C):NEXT C:
    NEXT I
319 NEXT R
320 FOR R=K1 TO 2 STEP -1:FOR I = R-1 TO 1 STEP -1:Z = B1(I,R)/B1(R,R):
    FOR C=R TO K2:B1(I,C)=B1(I,C)-Z*B1(R,C):NEXT C:
    NEXT I:NEXT R
321 FOR R=1 TO K1:Z = B1(R,R):
      FOR C=1 TO K2:B1(R,C)=B1(R,C)/Z:NEXT C:
    NEXT R
322 FOR R=1 TO N:FOR C=1 TO K1:
     FOR J=1 TO K1:B2(R,C)=B2(R,C)+B(J,R)*B1(J,C+K1):
      NEXT J:
    NEXT C:NEXT R
323 FOR R=1 TO N:FOR C=1 TO N:
     FOR J=1 TO K1:B3(R,C)=B3(R,C)+B2(R,J)*B(J,C):
      NEXT J:
    NEXT C:NEXT R
324 FOR R = 1 TO N : B3(R,R) = B3(R,R) - 1 : NEXT R
325 FOR R=1 TO N:FOR C=1 TO N:B3(R,C)=-1*B3(R,C):
    NEXT C:NEXT R
326 FOR R=1 TO N:FOR C=1 TO N:B3(R,C)=B3(R,C)*XOLD(C):
    NEXT C:NEXT R
327 FOR R=1 TO N:FOR C=1 TO N:CP(R)=CP(R)+B3(R,C)*CC(C):
    NEXT C:NEXT R
328 AA=0:FOR C=1 TO N : AA = AA + CP(C)*CP(C) : NEXT C
329 AA = SQR(AA) : FOR C=1 TO N : CP(C) = CP(C)/AA :
    NEXT C
330 AA = SQR(N*(N-1))/ALPHA
331 FOR C=1 TO N : XNEW(C) = (AO(C) - CP(C)/AA)*XOLD(C) :
    NEXT C
332 AA=0:FOR C=1 TO N : AA = AA + XNEW(C) : NEXT C
333 FOR C=1 TO N : XNEW(C) = XNEW(C)/AA : NEXT C
334 VNEW=0:FOR C=1 TO N:VNEW=VNEW+CC(C)*XNEW(C):NEXT C
335 '
336 ' FAILURE DETECTION routine based on equation (6) ...
337 '
338 ' You may wish to put this routine into KAREX1 and
    KAREX2 to
339 ' observe the values appearing in (6) during the solutions
340 ' of EXAMPLEs 1 and 2.
341 '
342 AA = 0
343 FOR C = 1 TO N
344 IF XNEW(C) > 0 THEN AA = AA + LOG(XNEW(C))
345 NEXT C
346 PRINT , LOG(VNEW/V), LOG(N) + AA/N - ITERATION/(8*N)
347 '
348 IF LOG(VNEW/V) > LOG(N) + AA/N - ITERATION/(8*N)
    THEN 400
349 '
350 WEND
351 '
```

```
400 PRINT : PRINT "Failure condition has occurred." :
    PRINT
401 PRINT USING "###"; ITERATION; :
    FOR C=1 TO N:PRINT USING "###.####";XNEW(C); :
    NEXT C : PRINT USING "####.########";VNEW/V
402 '
403 PRINT:FOR C=1 TO N-2:PRINT XNEW(C)/XNEW(N), :
    NEXT C:PRINT
404 '
405 END
```

BAM.PAS From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
program bam;
{ for further information
                        Rod Taber
                        General Dynamics
                        Electronics Division Mail Zone 7202-K
                        Box 85310
                        San Diego, CA 92138

Mail without the Mail Zone takes 3 months.}

{$R+,V+,K+,C-,U-}

const
  maxrows          = 12;
  maxcolumns       = 12;
  maxentries       = 144;
  maxpatterns      = 4;
  screenrows       = 24;
  screencolumns    = 80;

type
  threeD =         array[0..maxpatterns,1..1,1..maxentries] of integer;
  twoD   =         array[1..maxentries] of integer;
  oneD   =         array[1..maxentries] of integer;
  square =         array[1..maxentries,1..maxentries] of integer;
  Textin =         string[15];
var

  Ham:array[1..maxpatterns] of integer;
  Bipolar_A,Bipolar_B,Pattern_A,Pattern_B                :threeD;
  OriginalTestPattern,OutPatt                           :oneD;
  TestPattern,A_Check,B_Check                           :oneD;
  Rows_A,Rows_B,Columns_A,Columns_B                     :integer;
  MinHam,Num_Patterns,Length_A,Length_B                 :integer;
  Memory                                                :square;
  topline,bottomline,margin,leftone,rightone            :integer;
  lefttwo,leftthree,righttwo,rightthree,leftfour        :integer;
  energy                                                :real;
  threshold,pattern_number,TL,LL,AR,AC,PAC,PAR          :integer;
  test_type,Matrix_Used                                 :char;
  Synchmode,input,input_a,input_b                       :boolean;
  inputfile,outfle                                      :text;
  filename,filename2                                    :string[10];

{$I xface.inc}
{ ********************************************************************************** }
function max(x,y: integer): integer;
begin
  if x > y then max := x
        else max := y;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
function min(x,y: integer): integer;
```

continued

```
begin
  if x < y then min := x
        else min := y;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure zero_test;
var
  index:integer;
begin
  for index := 1 to maxentries do
    TestPattern[index] := 0;                { zero out Test matrix          }
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
Procedure Readcr(var charValue,errorCode:integer);
{Read the screen at cursor position}
type
  RegPack = record
            AL,AH,BL,BH,CL,CH,DL,DH     : Byte;
            BP,SI,DI,DS,ES,Flags        : Integer;
            end;
var
  Regs                : RegPack;

 begin
 with Regs do
             begin
               Errorcode:=0;  {assume no error}
               AH:=$8; BH:=$0;  {code 8- screen read, page 0}
               Intr($10,Regs);  {get character in AL via int 10h}
               charValue:= AL;  {used to be AL - 48 !!!!!}
             end;
 end; {Readcr}
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure Read_Row_and_Column_Values;

var
x:integer;
begin
 repeat
  textbackground(lightcyan);
  clrscr;                       { clears out any predefined user background }
  textmode(C80);
  textbackground(lightcyan);
  textcolor(red);
  GoToXY(8,4);
  write('B I D I R E C T I O N A L  A S S O C I A T I V E  M E M O R Y');
  GoToXY(8,7); Textcolor(blue);
  write('Enter the number of patterns to store.    < 1..',maxpatterns,' > ');
  readln(num_patterns);
  GoToXY(8,8);
  write('Enter the number of rows in pattern A:    < 1..',maxrows,' > ');
  readln(rows_a);
  GoToXY(8,9);
  write('Enter the number of columns in pattern A: < 1..',maxcolumns,' > ');
  readln(columns_a);
  GoToXY(8,10);
  write('Enter the number of rows in pattern B:    < 1..',maxrows,' > ');
  readln(rows_b);
  GoToXY(8,11);
  write('Enter the number of columns in pattern B: < 1..',maxcolumns,' > ');
  readln(columns_b);
  GoToXY(8,12);
  writeln('Enter the threshold of neuron activation:');
  GoToXY(10,13);
  write(' Value must be in range: - ',maxentries,', + ',maxentries,' ');
  readln(threshold);
  Length_A := Rows_A * Columns_A;
  Length_B := Rows_B * columns_B;
```

```
  TextColor(Red + Blink);    { blinks if inputs are unacceptable }
  if Length_A <= maxentries then input_a := True
    else
    begin
      input_a := False;
      GoToXY(13,17);
      writeln('Values for matrix A are out of bounds.');
      repeat until keypressed;
    end;
    if Length_B <= maxentries then input_b := True
      else
      begin
        input_b := False;
        GoToXY(13,17);
        writeln('Values for matrix B are out of bounds.');
        repeat until keypressed;
      end;
    if num_patterns < min(length_a,length_b) then input := True
      else
      begin
        input := False;
        GoToXY(13,17);
        writeln('Number of patterns must be less than ',min(length_a,length_b));
        repeat until keypressed;
      end;
    TextColor(Blue);
  until (input_a and input_b and input); { all inputs are within range }
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure UseCurrentScreenSetup;

begin
{   Synchmode  := True;
}   topline    := 5;
   bottomline := 15;
   margin     := 3;
   leftone    := 4;
   rightone   := 18;
   lefttwo    := 22;
   righttwo   := 36;
   leftthree  := 40;
   rightthree := 54;
   leftfour   := 58;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure SetMemoryToZero;
{$R+,V+,K+,C-,U-}

var
  index,row,column,size:integer;

begin
  size := max(length_a,length_b);
  for row := 1 to size do
    for column := 1 to size do
      memory[row,column] := 0;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
Procedure SaveScreen(Matrix_Used:char;row_in,column_in:integer);

var
  position,charValue,ErrorCode                    :integer;
begin
  position := 1;
    for AR := 1 to row_in do
      begin
        for AC := 1 to column_in do
          begin
            PAC:=LL+AC-1;
```

continued

```
            PAR:=TL+AR-1;
            GoToXY(PAC,PAR);
            Readcr(charValue,ErrorCode); Delay(2);
            if ErrorCode <> 0 then write('error');

            case Matrix_Used of
              'A': begin
                   if charValue = 177 then
                    Pattern_A[Pattern_Number,1,position] := 1
                   else
                    Pattern_A[Pattern_Number,1,position] := 0;
                  end;
              'B': begin
                   if charValue = 177 then
                    Pattern_B[Pattern_Number,1,position] := 1
                   else
                    Pattern_B[Pattern_Number,1,position] := 0;
                  end;
              'T': begin
                   if charValue = 177 then
                    TestPattern[position] := 1
                   else
                    TestPattern[position] := 0;
                  end;
            end; { end case }

            position := position + 1;
          end;
      end;

 { the following text erases the instructions yet leaves the Test Pattern }
 if Matrix_Used = 'T' then
 begin
   TextBackground(lightcyan);
   GoToXY(1,BottomLine + 4); { Beginning of instructions on screen }
   writeln('                          ');
   writeln('                            ');
   writeln('                           ');
   writeln('                               ');
 end;

end;
{ ********************************************************************************************* }

{ ********************************************************************************************* }
Procedure DataFromKeyboard (Matrix_Used:char; rows,columns:integer);

{PatternNumber must be defined prior to call}

var
char3                    :char;
intval                   :integer;
charValue                :integer;

label
     loop1,InitLoop;

begin
  TextBackground(lightgray);
  GoToXY(1,1);
  { only print heading for the first time this screen appears i.e., Matrix_a }
  if Matrix_Used <> 'B' then
  case Pattern_Number of
               0: begin
                   write('  Enter the Test Pattern');
                  end;

               1..MaxPatterns:
                  begin
                   TextColor(blue);
                   write('  Enter Pattern Number ',pattern_Number:2 );
                  end;
  end; {case}

  TextColor(blue);
  TextBackground(lightcyan);
```

```
   case Matrix_Used of
        'A' : begin                          { Matrix A input }
                GoToXY(LL,TL - 2);
                write('MATRIX A');
              end;
        'B' : begin                          { Matrix B input }
                GoToXY(lefttwo,TL - 2);
                write('MATRIX B');
              end;
        'T' : begin                          { TestPattern input }
                GoToXY(LL,TL - 2);
                write('TEST PATTERN');
              end;
   end; { end case }

   TextColor(Magenta);
   TextBackground(lightgray);

       for AR:= 1 to Rows do
         begin
          for AC:= 1 to Columns do
           begin
             PAC:=LL+AC-1;   {column to place cursor}
             PAR:=TL+AR-1;   {row to place cursor}
             GoToXY(PAC,PAR);
             write(chr(249));
             GoToXY(PAC,PAR);   { cursor stays in position }
           end;
        end;

{A zero matrix is now on the screen for Pattern 'PatternNumber'}

 TextColor(blue);                    { I N S T R U C T I O N S }
 TextBackground(lightcyan);
 GoToXY(1,BottomLine + 4);           { Next free line on screen }
 writeln('                  Position cursor using arrow keys.');
 writeln('                  Press period "." to change pattern.');
 writeln('                  Press space bar to remove changes.');
 write('  Press RETURN to store Matrix after entering complete pattern');

 Textbackground(lightgray);
 InitLoop: GoToXY(LL,TL); { cursor to first element of input pattern}
 AC:=LL;        {initialize row and column counters}
 AR:=TL;

loop1:read(kbd,char3);
      intval:=ord(char3);
      if intval = 27 then
                  begin
                    read(kbd,char3);
                    intval:=ord(char3);
                  end;

   case intval of           { beeps on attempt to move off pattern display }
        80: begin
             if AR + 1 >= Rows + TL then
              begin sound(800); delay(60); nosound; end
              else AR := AR+1; { down arrow}
            end;
        72: begin
             if AR - 1 < TL then
              begin sound(800); delay(60); nosound; end
              else AR := AR-1; {up arrow}
            end;
        75: begin
             if AC - 1 < LL then
             begin sound(800); delay(60); nosound; end
             else AC := AC-1; {left arrow}
            end;
        77: begin
             if AC + 1 >= Columns + LL then
             begin sound(800); delay(60); nosound; end
             else AC := AC+1; {right arrow}
            end;
```

continued

```
        46: begin          {digits}
             write(chr(177));
            end;
        32: begin
             textcolor(magenta);
             write(chr(249));
             textcolor(blue);
            end;
        13: begin
              SaveScreen(Matrix_Used,Rows,Columns); { works for Matrix A, B or Test }
            end;   {of case 13}

   end;{case statement}

   GoToXY(AC,AR); {goto new cursor position}
   if intval <> 13 then goto loop1;

TextBackground(lightcyan);
end; {DataFromKeyboard}
{ ************************************************************************************** }

{ ************************************************************************************** }
procedure EraseOldMatrices;

begin
  TextBackground(lightcyan);

{ clear old Matrix A }
  LL := leftone;
  for AR:= 1 to Rows_A do
  begin
    for AC:= 1 to Columns_A do
    begin
      PAC:=LL+AC-1; {column to place cursor}
      PAR:=TL+AR-1; {row to place cursor}
      GoToXY(PAC,PAR);
      write(' ');
    end;
  end;

{ clear old Matrix B }
  LL := lefttwo;
  for AR:= 1 to Rows_B do
  begin
    for AC:= 1 to Columns_B do
    begin
      PAC:=LL+AC-1; {column to place cursor}
      PAR:=TL+AR-1; {row to place cursor}
      GoToXY(PAC,PAR);
      write(' ');
    end;
  end;

end;
{ ************************************************************************************** }

{ ************************************************************************************** }
Procedure InputTestPattern;

var
  n:integer;

begin
  Pattern_Number := 0;
    for n := 1 to maxentries do
    begin
      A_Check[n] := 0;
      B_Check[n] := 0;
    end;
    TextColor(Red);
    repeat
       GoToXY(1,Bottomline + 2);
 writeln('                                                                    ');
 writeln('                                                                    ');
 writeln('                                                                    ');
 writeln('                                                                    ');
```

```
          GoToXY(1,Bottomline + 2);
          write('              Is test pattern of type A or B ? (A/B) ');
          readln(test_type);
        until test_type in ['a','A','b','B'];

        GoToXY(1,Bottomline + 2);          { erases 'Is test pattern of' query }
        writeln('                                                          ');

        { eliminate lowercase input and relace with uppercase equivalent }
        if test_type = 'a' then test_type := 'A';
        if test_type = 'b' then test_type := 'B';

        if test_type = 'A' then
        begin
          clrscr;
          TL := topline;       LL := leftone;
          DataFromKeyboard('T',rows_a,columns_a);
        end
        else
        begin  { if test_type = B }
          clrscr;
          TL := topline;       LL := leftone;
          DataFromKeyboard('T',rows_b,columns_b);
        end;
    OriginalTestPattern := TestPattern;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure ComputeEnergy;

var
    sum : real;
    temp: oneD;
    pattern_n,len_A,len_B,temp1: integer;

begin
 sum := 0.0;
 energy := 0.0;
 for pattern_n := 1 to num_patterns do
  begin
   for len_B := 1 to Length_B do
    begin
     temp[len_B] := 0;
     for len_A := 1 to Length_A do
      begin
temp1 := ( memory[len_A,len_B] - 0 );
       temp[len_B] := temp[len_B] + Pattern_A[pattern_n,1,len_A] * temp1;
      end;
    end;
   for len_B := 1 to Length_B do
      sum := sum + temp[len_B] * Pattern_B[pattern_n,1,len_B];
   energy := -sum;
  end;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure Hamming;

var
  n,j:integer;

begin
 for n := 1 to num_patterns do
    Ham[n] := 0;
 MinHam := 1;
 for n := 1 to num_patterns do
  begin
    if test_type = 'A' then
    begin
    for j := 1 to Length_A do
      if Pattern_A[n,1,j] <> OriginalTestPattern[j]
        then Ham[n] := Ham[n] + 1;
      if Ham[n] < Ham[MinHam] then MinHam := n;
```

continued

```
    end
    else
    begin
      for j := 1 to Length_B do
        if Pattern_B[n,1,j] <> OriginalTestPattern[j]
          then Ham[n] := Ham[n] + 1;
      if Ham[n] < Ham[MinHam] then MinHam := n;
    end;
  end;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure status(x,y:integer;TxT:textin);

var first:char;
    last :textin;

begin
  TextBackground(blue); { if status is not called from StatusLine }
  first := copy(TxT,1,1);
  last  := copy(TxT,2,(length(TxT) - 1));
  GoToXY(x,y);        Textcolor(white);      write(first);
  GoToXY(x + 1,y);    Textcolor(yellow);     write(last);
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
Procedure StatusLine;

var i:integer;  ch:char;

begin

 TextBackground(blue);
 GoToXY(1,23);
 for i := 1 to screencolumns do write(' '); { status line background }
 GoToXY(12,23); TextColor(Yellow);
 write('STATUS LINE - First letter of choice and RETURN selects:');
 GoToXY(1,24);
 for i := 1 to screencolumns do write(' '); { status line background }
 Status(15,24,'Quit');
 if SynchMode = True then Status(34,24,'Synch ')
                     else Status(34,24,'Asynch');
 Status(55,24,'Ham dist');
 GoToXY(15,20);
 write('Select execution Mode -- Synchronous/Asynchronous');
 repeat
   begin
     read(kbd,ch);
     if ch in ['s','S'] then SynchMode := True;
     if ch in ['a','A'] then SynchMode := False;
   end;
 until ch in ['a','A','s','S'];
 if SynchMode = True then Status(34,24,'Synch ')
                     else Status(34,24,'Asynch');
 Textbackground(lightcyan);Textcolor(blue);
 GoToXY(15,20);
 write('                                                    ');

end;{StatusLine}
{ ********************************************************************************** }

{ ********************************************************************************** }
Procedure TurnPCcursorOff;
{get rid of regular cursor}
type
    RegPack = record
              AL,AH,BL,BH,CL,CH,DL,DH : Byte;
              BP,SI,DI,DS,ES,Flags    : Integer;
              end;
var
  Regs                : RegPack;
```

```
 begin
   with Regs do
               begin
                AH:=$1; CH:=16;CL:= 0;
                Intr($10,Regs);
               end;
 end;{TurnPCcursorOff}
 { ********************************************************************************** }

 { ********************************************************************************** }
 Procedure TurnPCcursorOn;
 {turn on regular cursor}
 type
     RegPack = record
               AL,AH,BL,BH,CL,CH,DL,DH : Byte;
               BP,SI,DI,DS,ES,Flags    : Integer;
               end;
 var
   Regs                  : RegPack;

  begin
   with Regs do
               begin
                AH:=$1; CH:=7;CL:= 9; {start line>end means cursor off}
                Intr($10,Regs);
               end;
   end;  {TurnPCcursorOn}
 { ********************************************************************************** }

 { ********************************************************************************** }
 procedure BipolarizeB;

 var
   index:integer;

 begin
   for index := 1 to Length_B do
     begin
       if Pattern_B[Pattern_Number,1,index] = 0
         then Bipolar_B[Pattern_Number,1,index] := -1
         else Bipolar_B[Pattern_Number,1,index] := 1;
     end;
 end;
 { ********************************************************************************** }

 { ********************************************************************************** }
 procedure BipolarizeA;

 var
   index:integer;

 begin
   for index := 1 to Length_A do
     begin
       if Pattern_A[Pattern_Number,1,index] = 0
         then Bipolar_A[Pattern_Number,1,index] := -1
         else Bipolar_A[Pattern_Number,1,index] := 1;
     end;
 end;
 { ********************************************************************************** }

 { ********************************************************************************** }
 procedure Memorize_Bipolar;

 var
   pattern_n,len_A,len_B,temp : integer;

 begin
  GoToXY(4,bottomline + 2);
  write(' * Please wait - Bipolarization in Progress * ');
  for pattern_n := 1 to num_patterns do
   for len_A := 1 to Length_A do
    for len_B := 1 to Length_B do
      memory[len_a,len_b] := memory[len_a,len_b] +
                             bipolar_a[pattern_n,1,len_a] *
                             bipolar_b[pattern_n,1,len_b];
```

continued

```
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
function CheckIfKeypressed: boolean;
var
  ch:char; n,keyint: integer;

begin
  if not(keypressed) then CheckIfKeypressed := False
    else
    begin
      read(kbd,ch);
      keyint := ord(ch);
      case keyint of
          113,81 : CheckIfKeypressed := True;
                   { Q or q for Quit has been pressed }

          115,83 : begin    { S or s }
                     Synchmode := True;
                     Status(34,24,'Synch ');
                     CheckIfKeypressed := False; {continues execution}
                   end;

           97,65 : begin    { A or a }
                     Synchmode := False;
                     Status(34,24,'Asynch');
                     CheckIfKeypressed := False; {continues execution}
                   end;

          104,72 : begin
                     for n := 1 to num_patterns do
                       begin
                         GoToXY(16,18 + (n-1));
                         write('Hamming Distance for Pattern ' ,test_type);
                         writeln(' ',n,' is :',Ham[n]);
                       end;
                       GoToXY(20,22);
                       writeln('Press any key to continue ');
                     repeat until keypressed;
                       GoToXY(20,22);
                       writeln('                              ');
                     CheckIfKeypressed := False; {continues execution}
                     for n := 1 to num_patterns do
                       begin
                         GoToXY(16,18 + (n-1));
                         write('                                        ');
                         writeln('                    ');
                       end;
                   end;
          else   CheckIfKeypressed := False;
                   { no action taken }

      end; { end case }
    end;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
Procedure Bammer(Test_Pat:oneD; test_now:char;
                                leng1,leng2:integer);

var
  Memory_Transpose                  :Square;
  maxrow,n,k,i,j,m,y,Start,Finish   :integer;
  BinVect                           :OneD;

begin

 Textbackground(lightcyan);
 TextColor(blue);
 GoToXY(lefttwo,TL - 2);
 write('MATRIX A');
 GoToXY(leftthree,TL - 2);
 write('MATRIX B');
```

```
Textbackground(lightgray);
TextColor(magenta);

if Synchmode = True then
  begin              { Synchronous Mode prints out all Neurons }

    for j := 1 to leng1 do
        OutPatt[j] := 0;

    case test_now of
    'A' : begin
          B_Check := Test_Pat;

          for i := 1 to leng2 do
          if Test_Pat[i] = 0 then BinVect[i] := -1
                             else BinVect[i] := 1;

          for i := 1 to leng1 do
            for j := 1 to leng2 do
              Memory_Transpose[j,i] := Memory[i,j];

          for j := 1 to leng1 do
            for i := 1 to leng2 do
              OutPatt[j] := OutPatt[j] + BinVect[i] * Memory_Transpose[i,j];
          end;
    'B' : begin
          A_Check := Test_Pat;

          for i := 1 to leng2 do
           if Test_Pat[i] = 0 then BinVect[i] := -1
                              else BinVect[i] := 1;

          for i := 1 to leng1 do
            for j := 1 to leng2 do
              OutPatt[i] := OutPatt[i] + BinVect[j] * Memory[j,i];
          end;
end;   { end case }

for j := 1 to leng1 do
begin
  if (OutPatt[j] - threshold) > 0 then TestPattern[j] := 1
  else
  if (OutPatt[j] - threshold) < 0 then TestPattern[j] := 0
  else
    case test_now of
      'A' : TestPattern[j] := A_Check[j];
      'B' : TestPattern[j] := B_Check[j];
    end; { end case }
end; { end for Start to Finish }

case test_now of
'A':
    begin
      k := TL - 1;                          { prints out matrix A }
      for y := 0 to Length_A - 1 do
      begin
        i := y mod Columns_A;
        if i = 0 then k := k + 1;
        GoToXY(lefttwo + i,k);
        if TestPattern[y + 1] = 1 then write(chr(177))
                                  else write(chr(249));
      end;

      k := TL - 1;                          { prints out matrix B }
      for y := 0 to Length_B - 1 do
      begin
        i := y mod Columns_B;
        if i = 0 then k := k + 1;
        GoToXY(leftthree + i,k);
        if Test_Pat[y + 1] = 1 then write(chr(177))
                               else write(chr(249));
      end;
    end; { 'A' }
  'B':
   begin
```

continued

```
      k := 1;                              { prints out matrix A }
      for i := 0 to Rows_A - 1 do
      begin
        for j := 0 to Columns_A - 1 do
        begin
          GoToXY(lefttwo + j,TL + i);
          if Test_Pat[k] = 1 then write(chr(177))
                             else write(chr(249));
          k := k + 1;
        end;
      end;

      k := 1;                              { prints out matrix B }
      for i := 0 to Rows_B - 1 do
      begin
        for j := 0 to Columns_B - 1 do
        begin
          GoToXY(leftthree + j,TL + i);
          if TestPattern[k] = 1 then write(chr(177))
                                else write(chr(249));
          k := k + 1;
        end;
      end;
    end; { 'B' }
  end; { case test_now of }
end; { if Synchmode true }

if Synchmode = False then
begin                { Asynchronous Mode prints out one Neuron }

  for j := 1 to leng1 do
      OutPatt[j] := 0;

Case test_now of
  'A' : begin
          B_Check := Test_Pat;

          for i := 1 to leng2 do
          if Test_Pat[i] = 0 then BinVect[i] := -1
                             else BinVect[i] := 1;

          for i := 1 to leng1 do
            for j := 1 to leng2 do
              Memory_Transpose[j,i] := Memory[i,j];

          Start := Random(leng1);
          if Start = 0 then Start := leng1;

          for i := 1 to leng2 do
            OutPatt[Start] := OutPatt[Start] +
                              BinVect[i] * Memory_Transpose[i,Start];
        end;

  'B' : begin
          A_Check := Test_Pat;

          for i := 1 to leng2 do
          if Test_Pat[i] = 0 then BinVect[i] := -1
                             else BinVect[i] := 1;

          Start := Random(leng1);
          if Start = 0 then Start := leng1;

          for i := 1 to leng2 do
          OutPatt[Start] := OutPatt[Start] +
                            BinVect[i] * Memory[i,Start];
        end;
  end;   { end case }

  for j := 1 to leng1 do
  begin
    if (OutPatt[j] - threshold) > 0 then TestPattern[j] := 1
    else
    if (OutPatt[j] - threshold) < 0 then TestPattern[j] := 0
    else
```

```
            case test_now of
               'A' : TestPattern[j] := A_Check[j];
               'B' : TestPattern[j] := B_Check[j];
            end; { end case }
         end; { end for Start to Finish }

         case test_now of
          'A' : begin
                  k := TL - 1;                              { prints out matrix A }
                  for y := 0 to Length_A - 1 do
                  begin
                    i := y mod Columns_A;
                    if i = 0 then k := k + 1;
                    GoToXY(lefttwo + i,k);
                    if TestPattern[y + 1] = 1 then write(chr(177))
                                              else write(chr(249));
                  end;

                  k := TL - 1; { prints out matrix B }
                  for y := 0 to Length_B - 1 do
                  begin
                    i := y mod Columns_B;
                    if i = 0 then k := k + 1;
                    GoToXY(leftthree + i,k);
                    if Test_Pat[y + 1] = 1 then write(chr(177))
                                           else write(chr(249));
                  end;
         end; { 'A' }

         'B' : begin
                  k := 1;                                   { prints out matrix A }
                  for i := 0 to Rows_A - 1 do
                  begin
                    for j := 0 to Columns_A - 1 do
                    begin
                      GoToXY(lefttwo + j,TL + 1);
                      if Test_Pat[k] = 1 then write(chr(177))
                                         else write(chr(249));
                      k := k + 1;
                    end;
                  end;

                  k := 1;                                   { prints out matrix B }
                  for i := 0 to Rows_B - 1 do
                  begin
                    for j := 0 to Columns_B - 1 do
                      begin
                        GoToXY(leftthree + j,TL + 1);
                        if TestPattern[k] = 1 then write(chr(177))
                                              else write(chr(249));
                        k := k + 1;
                      end;
                  end;
                  end; { 'B' }
       end; { case test_now of }
     end; { end if Synchmode False }

  GoToXY(1,Bottomline + 2);
  TextBackground(lightcyan);
  TextColor(blue);

end;
{ ********************************************************************************************** }

{ ********************************************************************************************** }
procedure Bam;

begin

  GoToXY(1,1);          TextColor(Red);
  write('                       P R O C E S S I N G ');

  if test_type = 'A' then
    begin
      repeat
```

continued

```
        Bammer(TestPattern,'B',Length_B,Length_A);
        Bammer(TestPattern,'A',Length_A,Length_B);
      until CheckIfKeypressed;
    end
    else
    begin
      repeat
        Bammer(TestPattern,'A',Length_A,Length_B);
        Bammer(TestPattern,'B',Length_B,Length_A);
      until CheckIfKeypressed;
    end;

end;
{ ********************************************************************************** }

{ ********************************************************************************** }
function DataFromFile:boolean;

begin
  textbackground(lightcyan);
  clrscr;              { clears out any predefined user background }
  textmode(C80);
  textbackground(lightcyan);
  textcolor(red);
  GoToXY(8,4);
  write('B I D I R E C T I O N A L  A S S O C I A T I V E  M E M O R Y');
    DataFromFile := False;
  GoToXY(1,8);
  if yes('          Do you want to read the patterns from a file ? ') then
  begin
    GoToXY(1,9);
    write('          Enter the filename to read from: ');
    readln(filename);
    assign(inputfile,filename);
    {$I-}
    reset(inputfile);
    {$I+}
    DataFromFile := True;
    if not(ioresult = 0) then
    begin
      GoToXY(1,9); Textcolor(Red + Blink);
      writeln('Unable to open file ');
      exit;
    end;
  end;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
procedure ReadInFile;
var
  temp:integer; ch:char;

begin
  TurnPCcursorOff;
  readln(inputfile,num_patterns);
  readln(inputfile,Rows_A);
  readln(inputfile,Columns_A);
  readln(inputfile,Rows_B);
  readln(inputfile,Columns_B);
  Length_A := Rows_A * Columns_A;
  Length_B := Rows_B * columns_B;
  clrscr;
  textcolor(blue);          TL := topline;
  GoToXY(1,1);
  write('Reading Patterns from file: ',filename);
  GoToXY(leftone,TL - 2);
  write('MATRIX A');
  GoToXY(lefttwo,TL - 2);
  write('MATRIX B');
  textbackground(lightgray);
  textcolor(magenta);
  for Pattern_Number := 1 to num_patterns do
  begin
  GoToXY(13,bottomline + 1);
  write('Pattern ',Pattern_Number);
```

```
        TL := topline;          LL := leftone;
        for AR := 1 to Rows_A do
          begin
          for AC := 1 to Columns_A do
            begin
              PAC := LL + AC - 1;
              PAR := TL + AR - 1;
              GoToXY(PAC,PAR);
              read(inputfile,temp);
              if temp = 1 then write(chr(177))
                          else write(chr(249));
            end;
          end;

       LL := lefttwo; TL := topline;
       for AR := 1 to Rows_B do
         begin
         for AC := 1 to Columns_B do
           begin
             PAC := LL + AC - 1;
             PAR := TL + AR - 1;
             GoToXY(PAC,PAR);
             read(inputfile,temp);
             if temp = 1 then write(chr(177))
                         else write(chr(249));
           end;
         end;

        LL := leftone; TL := topline;
        SaveScreen('A',Rows_A,Columns_A);
        LL := lefttwo; TL := topline;
        SaveScreen('B',Rows_B,Columns_B);
        BipolarizeB;
        BipolarizeA;

        GoToXY(8,bottomline + 2);   Textbackground(lightcyan);
        Textcolor(red);  write('Press any key to continue reading patterns.');
        repeat until keypressed;
        read(kbd,ch);
        GoToXY(8,bottomline + 2);   Textbackground(lightcyan);
        write('                              '); { erase above }
        Textcolor(magenta); Textbackground(lightgray);

    end; { for Pattern_Number }
    textcolor(blue);              Textbackground(lightcyan);
    GoToXY(4, bottomline + 1);       TurnPCcursorOn;
    writeln('Enter the threshold of neuron activation:');
    GoToXY(4,bottomline + 2);
    write(' Value must be in range: - ',maxentries,', + ',maxentries,' ');
    readln(threshold);              TurnPCcursorOff;
    GoToXY(4, bottomline + 1);
    writeln('                              ');
  end;
{ ************************************************************************************** }

{ ************************************************************************************** }
Procedure WriteToFile;
var n,z:integer;
begin
   if yes(' Do you want to save the memory patterns to a file ? ') then
     begin
       write(' Enter the filename to save patterns to: ');
       readln(filename2);
       assign(outfle,filename2);
       rewrite(outfle);
        writeln(outfle,num_patterns);
        writeln(outfle,Rows_A);
        writeln(outfle,Columns_A);
        writeln(outfle,Rows_B);
        writeln(outfle,Columns_B);
        for n := 1 to num_patterns do
          begin
            for z := 1 to Length_A do
              write(outfle,Pattern_A[n,1,z],' ');
            writeln(outfle);
```

continued

```
            for z := 1 to Length_B do
              write(outfle,Pattern_B[n,1,z],' ');
            writeln(outfle);
          end;
        close(outfle);
    end;
end;
{ ********************************************************************************** }

{ ********************************************************************************** }
begin { MAIN }
 repeat { until not 'yes try another set of patterns ' }
  UseCurrentScreenSetup;
  if DataFromFile = False then
  begin { input is from the keyboard }
    Read_Row_and_Column_Values;
    SetMemoryToZero;
    clrscr;
    for Pattern_Number := 1 to num_patterns do
     begin
      TL := topline;       LL := leftone;
      DataFromKeyboard('A',rows_a,columns_a);
      TL := topline;       LL := lefttwo;
      DataFromKeyboard('B',rows_b,columns_b);
      BipolarizeB;
      BipolarizeA;
      if Pattern_Number <> num_patterns then EraseOldMatrices;
    end;
  end  { input is from the keyboard }
  else { input is from the files     }
    ReadInFile;
    SetMemoryToZero;

  Memorize_Bipolar;
  ComputeEnergy;
  TurnPCcursorOn;
  repeat { until not yes 'another test pattern ' }
    zero_test;
    InputTestPattern;
    Hamming;
    TurnPCcursorOff;
    StatusLine;
    Bam;
    TurnPCcursorOn;
    WriteToFile;
  until not yes(' Do you want to try another test pattern ? ');
until not yes(' Do you want to try another set of patterns ? ');
TextMode; { returns screen to previous graphics color mode }
clrscr;
end.
```

XFACE.INC From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
type
  mstring = string[100];
var
  outfile : text;

 FUNCTION yes(PROMPT:MSTRING): BOOLEAN;
  var
     ch : string[2];
   begin
     (*$I-*)(*$R-*)
     repeat
       write(prompt,' (y/n) ');
       readln(ch);
     until (ch ='y') or (ch = 'Y') or (ch ='N') or (ch ='n') and (ioresult=0);
     (*$I+*)(*$R+*)
     yes := (ch ='y') or (ch ='Y');
   end;
```

```
PROCEDURE setoutfile;
  var
    ch: char;
  begin
    (*$I-*)(*$R-*)
    repeat
     write('OUTPUT DESTINATION: P(rinter C(onsole : ');
     readln(ch);
    until (ch in['c','C','p','P']) and (ioresult = 0);
    case ch of
      'p','P' : ASSIGN(outfile,'LST:');
      'c','C' : ASSIGN(outfile,'CON:');
    end; (*case*)
    REWRITE(OUTFILE);
    (*$I+*)(*$R+*)
  end; (*setoutfile*)


FUNCTION getnum(PROMPT:MSTRING; LOW,HIGH:INTEGER):INTEGER;
  var
    val : integer;
  begin
    VAL := -31695;
    (*$I-*)(*$R-*)
    repeat
      write(prompt,'(',low,'..',high,'): ');
      readln(val);
      if (val < low) or (val > high)
       then writeln(' VALUE OUT OF RANGE ');
      if ioresult <> 0
        then writeln('WRONG DATA TYPE ');
    until (val >= low) and (val <= high) and (ioresult = 0);
    getnum := val;
    (*$I+*)(*$R+*)
  end;

FUNCTION getchar(PROMPT:MSTRING):CHAR;
 var
  ch : char;
 begin
   (*$I-*)(*$R-*)
   repeat
     write(prompt);
     readln(ch);
   until (ch IN ['a'..'z','A'..'Z']) and (ioresult = 0);
   getchar := ch;
   (*$I+*)(*$R+*)
 end;

FUNCTION getreal(PROMPT:MSTRING; LOW,HIGH:REAL):REAL;
  var
    val : real;
  begin
    VAL := -31695.7;
    (*$I-*)(*$R-*)
    repeat
      write(prompt,'(',low:3:1,'..',high:3:1,'): ');
      readln(val);
      if (val < low) or (val > high) or (ioresult <> 0)
        then writeln(' Data incorrect type or out of range ');
    until (val <= low) and (val <= high) and (ioresult = 0);
      getreal := val;
      (*$I+*)(*$R+*)
  end;
```

continued

BAM.BAS From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
1000 CLS
1010 PRINT
1020 PRINT
1030 PRINT
1040 PRINT "          ********************************************************************"
1050 PRINT "          *                                                                  *"
1060 PRINT "          *                  BIDIRECTIONAL ASSOCIATIVE MEMORY                *"
1070 PRINT "          *                       DEMONSTRAION PROGRAM                       *"
1080 PRINT "          *                                                                  *"
1090 PRINT "          *          (C) COPYRIGHT 1987 LOGICAL DESIGNS CONSULTING INC.      *"
1100 PRINT "          *                    3229 ERIE ST. SAN DIEGO, CA 92117             *"
1110 PRINT "          *                            (619) 276-3955                        *"
1120 PRINT "          *                                                                  *"
1130 PRINT "          *                          BY DUANE DESIENO                        *"
1140 PRINT "          *                                                                  *"
1150 PRINT "          ********************************************************************"
1160 PRINT
1170 PRINT
1180 PRINT
1190 PRINT
1200 PRINT "          PRESS (Y) FOR INSTRUCTIONS"
1210 S$=INKEY$
1220 IF LEN(S$)=0 THEN GOTO 1210
1230 IF S$<>"Y" AND S$<>"y" THEN GOTO 1760
1240 CLS
1250 PRINT
1260 PRINT "          USING THE BAM DEMONSTRATION PROGRAM"
1270 PRINT
1280 PRINT " - CHANGE NETWORK PARAMETERS to set new values of the A and B"
1290 PRINT "  dimensions, the number of cells updated per iteration of the"
1300 PRINT "  network, and the percentage of elements to change state when"
1310 PRINT "  random noise is added to the A and B fields. The maximun"
1320 PRINT "  size of the A or B fields is 144 elements (12x12)."
1330 PRINT
1340 PRINT " - CLEAR NETWORK fills the matrix M with 0. All stored patterns"
1350 PRINT "  will be lost when this command is executed, so be sure to"
1360 PRINT "  save the M matrix before executing this command."
1370 PRINT
1380 PRINT " - LOAD MEMORY MATRIX M displays all current BAM interconnect"
1390 PRINT "  matrix files stored on disk. Enter the desired filename"
1400 PRINT "  to load that file into the M matrix."
1410 PRINT
1420 PRINT " - SAVE MEMORY MATRIX M to store the current M matrix to a disk"
1430 PRINT "  file. The dimensions of the A and B fields are also saved."
1440 PRINT
1450 PRINT
1460 PRINT "          PRESS ANY KEY TO CONTINUE"
1470 S$=INKEY$
1480 IF LEN(S$)=0 THEN GOTO 1470
1490 CLS
1500 PRINT
1510 PRINT " - EDIT/RUN NETWORK to input new patterns to the A and B fields."
1520 PRINT "  Once input, the network can either learn the new pattern or"
1530 PRINT "  execute one or more iterations of the network."
1540 PRINT
1550 PRINT " - LEARN CURRENT PATTERN takes the current state of the A and B"
1560 PRINT "  fields and changes the M matrix to learn this pattern. The"
1570 PRINT "  cursor will disappear until this operation is complete."
1580 PRINT
1590 PRINT " - ADD RANDOM NOISE will flip the state of a certain percentage"
1600 PRINT "  of elements in both the A and B fields. The percentage is"
1610 PRINT "  set in the NETWORK PARAMETERS. This can be used to see how"
1620 PRINT "  different a pattern can be to still be recalled."
1630 PRINT
1640 PRINT " - RUN THE NETWORK will execute two complete iterations of the"
1650 PRINT "  network when the parameter is set for synchronous operation."
1660 PRINT "  When the number of cells updated per iteration is greater "
1670 PRINT "  than 0, 10 iterations of the network are executed. At each"
1680 PRINT "  iteration, only the number of cells specified in the parameter"
1690 PRINT "  are updated per field."
1700 PRINT
1710 PRINT
```

```
1720 PRINT "              PRESS ANY KEY TO CONTINUE"
1730 S$=INKEY$
1740 IF LEN(S$)=0 THEN GOTO 1730
1750 REM
1760 ON ERROR GOTO 4720
1770 DIM A%(144),B%(144),X%(144),Y%(144),M%(144,144)
1780 AXSIZE=12: AYSIZE=12: BXSIZE=12: BYSIZE=12
1790 CLS
1800 KEY OFF
1810 PRINT "                                  BIDIRECTIONAL ASSOCIATIVE MEMORY "
1820 PRINT "                                        DEMONSTRATION PROGRAM"
1830 PRINT
1840 PRINT
1850 PRINT "                                              BY DUANE DESIENO"
1860 PRINT
1870 PRINT
1880 PRINT
1890 PRINT "                                                 MAIN MENU"
1900 PRINT
1910 PRINT "                                  1 - CHANGE NETWORK PARAMETERS"
1920 PRINT "                                  2 - CLEAR NETWORK"
1930 PRINT "                                  3 - LOAD MEMORY MATRIX M"
1940 PRINT "                                  4 - SAVE MEMORY MATRIX M"
1950 PRINT "                                  5 - EDIT/RUN NETWORK"
1960 PRINT "                                  6 - QUIT"
1970 PRINT
1980 INPUT "                                  INPUT CHOICE (1-6): "; CHOICE
1990     ON CHOICE GOSUB 2010,2370,4240,4480,3000,4750
2000     GOTO 1790 'THIS IS THE MAIN LOOP OF THE PROGRAM
2010 REM ************************************************
2020 REM                CHANGE NETWORK PARAMETERS
2030 REM ************************************************
2040 CLS
2050 LOCATE 5,1
2060 PRINT "                                  CURRENT NETWORK PARAMETERS"
2070 PRINT
2080 PRINT
2090 PRINT "                          1 - A FIELD X DIMENSION                    : ";AXSIZE
2100 PRINT "                          2 - A FIELD Y DIMENSION                    : ";AYSIZE
2110 PRINT "                          3 - B FIELD X DIMENSION                    : ";BXSIZE
2120 PRINT "                          4 - B FIELD Y DIMENSION                    : ";BYSIZE
2130 PRINT "                          5 - NUMBER OF CELLS CHANGED PER "
2140 PRINT "                              ITERATION (0=SYNCHRONOUS)              : ";ASYN
2150 PRINT "                          6 - RANDOM NOISE PERCENTAGE                : ";NOISE
2160 PRINT "                          7 - RETURN"
2170 PRINT
2180 INPUT "            ENTER CHOICE :";CHOICE
2190 IF CHOICE=7 THEN GOTO 2290
2200 INPUT "            ENTER NEW VALUE :";NVAL
2210 ON CHOICE GOTO 2230,2240,2250,2260,2270,2280
2220 RETURN
2230   AXSIZE=NVAL: GOTO 2010              ' LOOP TILL DONE
2240   AYSIZE=NVAL: GOTO 2010
2250   BXSIZE=NVAL: GOTO 2010
2260   BYSIZE=NVAL: GOTO 2010
2270   ASYN=NVAL: GOTO 2010
2280   NOISE=NVAL: GOTO 2010
2290   IF AXSIZE*AYSIZE>144 THEN PRINT "A FIELD TOO LARGE";: GOTO 2050
2300   IF AYSIZE>16 THEN PRINT "A FIELD Y DIM TOO LARGE";: GOTO 2050
2310   IF BXSIZE*BYSIZE>144 THEN PRINT "B FIELD TOO LARGE";: GOTO 2050
2320   IF BYSIZE>16 THEN PRINT "B FIELD Y DIM TOO LARGE";: GOTO 2050
2330 RETURN          ' END OF CHANGE NETWORK PARAMETERS
2340 REM ************************************************
2350 REM               CLEAR NETWORK MATRIX M,A,B
2360 REM ************************************************
2370 FOR I=1 TO 144
2380   A%(I)=0
2390   B%(I)=0
2400 NEXT I
2410 FOR I=1 TO AXSIZE*AYSIZE   'CLEAR THE MEMORY MATRIX M
2420   FOR J=1 TO BXSIZE*BYSIZE
2430     M%(I,J)=0
2440   NEXT J
2450   PRINT ".";
```

continued

```
2460 NEXT I
2470 RETURN             ' END OF CLEAR NETWORK
2480 REM ************************************
2490 REM            DISPLAY A AND B FIELDS
2500 REM ************************************
2510 CLS
2520 LOCATE 1,19: PRINT "A FIELD";
2530 LOCATE 1,59: PRINT "B FIELD";
2540 REM **** DRAW BOX AROUND A FIELD ****
2550 LOCATE 3,15: PRINT CHR$(218)
2560 FOR I=1 TO AXSIZE: LOCATE 3,15+I: PRINT CHR$(196);: NEXT I
2570 PRINT CHR$(191);
2580 FOR J=1 TO AYSIZE
2590    LOCATE 3+J,15: PRINT CHR$(179);
2600    LOCATE 3+J,15+AXSIZE+1: PRINT CHR$(179);
2610 NEXT J
2620 LOCATE 3+AYSIZE+1,15: PRINT CHR$(192);
2630 FOR I=1 TO AXSIZE: LOCATE 3+AYSIZE+1,15+I: PRINT CHR$(196);: NEXT I
2640 PRINT CHR$(217);
2650 REM **** DRAW BOX AROUND B FIELD ****
2660 LOCATE 3,55: PRINT CHR$(218)
2670 FOR I=1 TO BXSIZE: LOCATE 3,55+I: PRINT CHR$(196);: NEXT I
2680 PRINT CHR$(191);
2690 FOR J=1 TO BYSIZE
2700    LOCATE 3+J,55: PRINT CHR$(179);
2710    LOCATE 3+J,55+BXSIZE+1: PRINT CHR$(179);
2720 NEXT J
2730 LOCATE 3+BYSIZE+1,55: PRINT CHR$(192)
2740 FOR I=1 TO BXSIZE: LOCATE 3+BYSIZE+1,55+I: PRINT CHR$(196);: NEXT I
2750 PRINT CHR$(217);
2760 LOCATE 21,1:PRINT "OPTIONS:  1. LEARN CURRENT PATTERN";
2770 LOCATE 21,41:PRINT "            ARROW KEYS TO MOVE CURSOR";
2780 LOCATE 22,1:PRINT "          2. ADD RANDOM NOISE";
2790 LOCATE 22,41:PRINT "            A OR B TO SWITCH FIELDS"
2800 LOCATE 23,1:PRINT "          3. RUN THE NETWORK";
2810 LOCATE 23,41:PRINT "            + TO SET LEVEL TO 1";
2820 LOCATE 24,1:PRINT "          4. CLEAR A AND B FIELDS";
2830 LOCATE 24,41:PRINT "            - TO SET LEVEL TO 0";
2840 LOCATE 25,1:PRINT "        ESC. RETURN TO MAIN MENU";
2850 REM **** DISPLAY THE A FIELD ARRAY IN THE BOX ****
2860 FOR J=1 TO AYSIZE
2870   FOR I=1 TO AXSIZE
2880     LOCATE 3+J,15+I
2890     PRINT CHR$(219*A%((J-1)*AXSIZE+I));
2900   NEXT I
2910 NEXT J
2920 REM **** DISPLAY THE B FIELD ARRAY IN THE BOX ****
2930 FOR J=1 TO BYSIZE
2940   FOR I=1 TO BXSIZE
2950     LOCATE 3+J,55+I
2960     PRINT CHR$(219*B%((J-1)*BXSIZE+I));
2970   NEXT I
2980 NEXT J
2990 RETURN
3000 REM ************************************************
3010 REM                  EDIT THE A AND B FIELDS
3020 REM ************************************************
3030 GOSUB 2480              'DISPLAY THE FIELDS BEFORE EDITING
3040 PX=1: PY=1: FLD=0       'START ON A FIELD UPPER LEFT CORNER
3050 S$=INKEY$               'GET KEYBOARD ENTRY
3060 LOCATE 3+PY,15+PX+40*FLD          'POSITION CURSOR IN FIELD BOX
3070 PRINT "*";
3080 FOR ZZ=1 TO 4: NEXT ZZ
3090 LOCATE 3+PY,15+PX+40*FLD
3100 IF FLD=0 THEN XSIZE=AXSIZE: YSIZE=AYSIZE
3110 IF FLD=1 THEN XSIZE=BXSIZE: YSIZE=BYSIZE
3120 OFS=((PY-1)*XSIZE+PX)
3130 IF FLD=0 THEN STAT=A%(OFS) ELSE STAT=B%(OFS)
3140 PRINT CHR$(219*STAT);
3150 IF LEN(S$)=2 THEN S$=RIGHT$(S$,1)
3160 IF S$=CHR$(77) THEN PX=PX+1
3170 IF S$=CHR$(75) THEN PX=PX-1
3180 IF S$=CHR$(72) THEN PY=PY-1
3190 IF S$=CHR$(80) THEN PY=PY+1
3200 IF S$="A" OR S$="a" THEN FLD=0: PX=1: PY=1
3210 IF S$="B" OR S$="b" THEN FLD=1: PX=1: PY=1
3220 IF S$="+" AND FLD=0 THEN A%(OFS)=1
```

```
3230 IF S$="+" AND FLD=1 THEN B%(OFS)=1
3240 IF S$="-" AND FLD=0 THEN A%(OFS)=0
3250 IF S$="-" AND FLD=1 THEN B%(OFS)=0
3260 IF S$="1" THEN GOSUB 3370                  ' LEARN CURRENT PATTERN
3270 IF S$="2" THEN GOSUB 3530                  ' ADD RANDOM NOISE TO PATTERN
3280 IF S$="3" THEN GOSUB 3660                  ' RUN THE NETWORK
3290 IF S$="4" THEN GOSUB 4150                  ' CLEAR THE A AND B FIELDS
3300 IF PX<1 THEN PX=1
3310 IF PX>XSIZE THEN PX=1: PY=PY+1
3320 IF PY<1 THEN PY=1
3330 IF PY>YSIZE THEN PY=YSIZE
3340 IF S$=CHR$(27) THEN RETURN
3350 FOR ZZ=1 TO 4: NEXT ZZ
3360 GOTO 3050
3370 REM ******************************************************
3380 REM            LEARN CURRENT PATTERN IN A AND B FIELDS
3390 REM ******************************************************
3400 FOR I=1 TO AXSIZE*AYSIZE              ' TRANSFER A FIELD TO BIPOLAR X FIELD
3410   IF A%(I)=0 THEN X%(I)=-1 ELSE X%(I)=1
3420 NEXT I
3430 FOR I=1 TO BXSIZE*BYSIZE              ' TRANSFER B FIELD TO BIPOLAR Y FIELD
3440   IF B%(I)=0 THEN Y%(I)=-1 ELSE Y%(I)=1
3450 NEXT I
3460 REM **** THE CORRELATION MATRIX M IS UPDATED HERE ****
3470 FOR J=1 TO BXSIZE*BYSIZE
3480   FOR I=1 TO AXSIZE*AYSIZE
3490     M%(I,J)=M%(I,J)+X%(I)*Y%(J)
3500   NEXT I
3510 NEXT J
3520 RETURN
3530 REM ******************************************************
3540 REM            ADD RANDOM NOISE TO THE A AND B FIELDS
3550 REM ******************************************************
3560 FOR I=1 TO AXSIZE*AYSIZE
3570   IF 100*RND>=NOISE THEN 3590
3580   IF A%(I)=0 THEN A%(I)=1 ELSE A%(I)=0   'FLIP THE STATE
3590 NEXT I
3600 FOR I=1 TO BXSIZE*BYSIZE
3610   IF 100*RND>=NOISE THEN 3630
3620   IF B%(I)=0 THEN B%(I)=1 ELSE B%(I)=0   'FLIP THE STATE
3630 NEXT I
3640 GOSUB 2850   'UPDATE THE A AND B FIELD DISPLAYS
3650 RETURN
3660 REM ******************************************************
3670 REM                RUN ITERATIONS OF THE NETWORK
3680 REM ******************************************************
3690 IF ASYN=0 THEN GOTO 3940
3700 REM **** PERFORM ASYNCHRONOUS UPDATE OF ASYN RANDOM NEURONS/FIELD ****
3710 FOR CC=1 TO 10   ' LIMIT THE NUMBER OF ASYNCHRONOUS ITERATIONS
3720   FOR K=1 TO ASYN
3730     PIK=INT((AXSIZE*AYSIZE)*RND+1)
3740     TSUM = 0
3750     FOR J=1 TO BXSIZE*BYSIZE              'UPDATE A FIELD NEURON
3760       TSUM = TSUM + B%(J)*M%(PIK,J)
3770     NEXT J
3780     IF TSUM>0 THEN A%(PIK)=1   ' THRESHOLD FUNCTION
3790     IF TSUM<0 THEN A%(PIK)=0
3800   NEXT K
3810   FOR K=1 TO ASYN
3820     PIK=INT((BXSIZE*BYSIZE)*RND+1)
3830     TSUM = 0
3840     FOR I=1 TO AXSIZE*AYSIZE              'UPDATE B FIELD NEURON
3850       TSUM = TSUM + A%(I)*M%(I,PIK)
3860     NEXT I
3870     IF TSUM>0 THEN B%(PIK)=1   ' THRESHOLD FUNCTION
3880     IF TSUM<0 THEN B%(PIK)=0
3890   NEXT K
3900   GOSUB 2850   'WANT TO WATCH THE PROGRESS
3910 NEXT CC
3920 RETURN            ' COMPLETED ASYN ITERATION
3930 REM **** PERFORM SYNCHRONOUS UPDATE OF ALL NEURONS IN BOTH FIELDS ****
3940 FOR CC = 1 TO 2   ' ONLY TWO ITERATIONS NEEDED
3950   FOR J=1 TO BXSIZE*BYSIZE
3960     TSUM = 0
3970     FOR I=1 TO AXSIZE*AYSIZE              'UPDATE B FIELD NEURON
```

continued

```
3980        TSUM = TSUM + A%(I)*M%(I,J)
3990      NEXT I
4000      IF TSUM>0 THEN B%(J)=1   ' THRESHOLD FUNCTION
4010      IF TSUM<0 THEN B%(J)=0
4020    NEXT J
4030    FOR I=1 TO AXSIZE*AYSIZE
4040      TSUM = 0
4050      FOR J=1 TO BXSIZE*BYSIZE              'UPDATE A FIELD NEURON
4060        TSUM = TSUM + B%(J)*M%(I,J)
4070      NEXT J
4080      IF TSUM>0 THEN A%(I)=1   ' THRESHOLD FUNCTION
4090      IF TSUM<0 THEN A%(I)=0
4100    NEXT I
4110    GOSUB 2850        'UPDATE THE A AND B FIELD DISPLAYS
4120 NEXT CC    ' ITERATION OF BOTH FIELDS
4130 RETURN
4140 RETURN
4150 REM ************************************
4160 REM           CLEAR THE A AND B FIELDS
4170 REM ************************************
4180 FOR I=1 TO 144
4190    A%(I)=0
4200    B%(I)=0
4210 NEXT I
4220 GOSUB 2850   'UPDATE THE A AND B FIELD DISPLAYS
4230 RETURN
4240 REM ************************************************
4250 REM          LOAD CORRELATION MATRIX M FROM DISK FILE
4260 REM ************************************************
4270 CLS
4280 PRINT "              CURRENT MEMORY MATRIX FILES ON DISK"
4290 PRINT
4300 FILES "*.BAM"
4310 PRINT
4320 PRINT
4330 INPUT "           ENTER FILENAME TO LOAD MEMORY MATRIX : "; FILESPEC$
4340 IF FILESPEC$ = " " THEN RETURN
4350 IF INSTR(".",FILESPEC$) = 0 THEN FILESPEC$ = FILESPEC$ + ".BAM"
4360 OPEN FILESPEC$ FOR INPUT AS #1
4370 INPUT #1, AXSIZE
4380 INPUT #1, AYSIZE
4390 INPUT #1, BXSIZE
4400 INPUT #1, BYSIZE
4410 FOR J=1 TO BXSIZE*BYSIZE
4420    FOR I=1 TO AXSIZE*AYSIZE
4430      INPUT #1, M%(I,J)
4440    NEXT I
4450 NEXT J
4460 CLOSE #1
4470 RETURN
4480 REM ************************************************
4490 REM           SAVE CORRELATION MATRIX M TO DISK FILE
4500 REM ************************************************
4510 CLS
4520 PRINT "              CURRENT MEMORY MATRIX FILES ON DISK"
4530 PRINT
4540 FILES "*.BAM"
4550 PRINT
4560 PRINT
4570 INPUT "           ENTER FILENAME TO SAVE MEMORY MATRIX : "; FILESPEC$
4580 IF FILESPEC$ = " " THEN RETURN
4590 IF INSTR(".",FILESPEC$) = 0 THEN FILESPEC$ = FILESPEC$ + ".BAM"
4600 OPEN FILESPEC$ FOR OUTPUT AS #1
4610 PRINT #1, AXSIZE
4620 PRINT #1, AYSIZE
4630 PRINT #1, BXSIZE
4640 PRINT #1, BYSIZE
4650 FOR J=1 TO BXSIZE*BYSIZE
4660    FOR I=1 TO AXSIZE*AYSIZE
4670      PRINT #1, M%(I,J)
4680    NEXT I
4690 NEXT J
4700 CLOSE #1
4710 RETURN
4720 IF ERL=4540 THEN PRINT "NO FILES": RESUME 4550
4730 IF ERL=4300 THEN PRINT "NO FILES": RESUME 4310
```

```
4740 RESUME 1790
4750 CLOSE
4760 ON ERROR GOTO 0
4770 END
```

SORTELEM.MOD From "Programming Project: Crafting Reusable Software in Modula-2" by Hanna Oktaba and René Berber, BYTE, September 1987.

```
IMPLEMENTATION MODULE SortElemType;

                (* FROM FileDescriptor IMPORT FileDescr; *)
                FROM InOut IMPORT in, ReadString, WriteString, WriteLn, Write;
                FROM Storage IMPORT ALLOCATE;
                FROM Strings IMPORT Length, Concat, Copy;
CONST
                EOS = 0C;                           (* End Of String *)
TYPE
                ElemType = POINTER TO FileDescr;
                FileDescr = RECORD(* File descriptor *)
                          name : ARRAY [0..8] OF CHAR;
                          ext  : ARRAY [0..3] OF CHAR;
                          size : ARRAY [0..7] OF CHAR;
                          date : ARRAY [0..8] OF CHAR;
                          time : ARRAY [0..6] OF CHAR
                      END;
VAR
                comp : PROCEDURE(ElemType,ElemType): BOOLEAN;

PROCEDURE compare (x, y: ElemType): BOOLEAN;
BEGIN                   (* call the procedure currently *)
  RETURN comp(x,y)      (* assigned to "comp"*)
END compare;

PROCEDURE compName (r1, r2: ElemType): BOOLEAN;
BEGIN
  RETURN StringComp(r1^.name,r2^.name)
END compName;

PROCEDURE compExt (r1, r2: ElemType): BOOLEAN;
  VAR temp1, temp2 : ARRAY [0..12] OF CHAR;
BEGIN (* compare by extension and then by name *)
  Concat(r1^.ext,".",temp1);  Concat(temp1,r1^.name,temp1);
  Concat(r2^.ext,".",temp2);  Concat(temp2,r2^.name,temp2);
  RETURN StringComp(temp1,temp2)
END compExt;

PROCEDURE select (option: CARDINAL);
BEGIN
  CASE option OF                                    (* compare by:          *)
       1 : comp:= compName                          (*    filenames         *)
  | 2 : comp:= compExt                      (*extension                      *)
  ELSE comp:= compName                              (* default              *)
  END
END select;

PROCEDURE optionMenu;
BEGIN
  WriteString("options:"); WriteLn;
  WriteString("          1  to sort by filename"); WriteLn;
  WriteString("          2  to sort by extension"); WriteLn;
  WriteString(" the default is 1, any other is taken as 1");
  WriteLn; WriteLn
END optionMenu;

PROCEDURE ReadArray(VAR A: ARRAY OF ElemType): CARDINAL;
  VAR n, max : CARDINAL;
        temp  : ARRAY [0..8] OF CHAR;
```

continued

```
BEGIN
  n:= 0; max:= HIGH(A);
  ReadString(temp);
  WHILE (NOT in.eof) & (n < max) DO
        NEW(A[n]);
        Copy(temp,0,30,A[n]^.name);
        ReadString(A[n]^.ext);
        ReadString(A[n]^.size);
        ReadString(A[n]^.date);
        ReadString(A[n]^.time);
        ReadString(temp); INC(n)
  END;
  RETURN n
END ReadArray;

PROCEDURE WriteArray(A: ARRAY OF ElemType; n: CARDINAL);
  VAR i : CARDINAL;
BEGIN
  FOR i:= 0 TO n-1 DO
        WriteFString(A[i]^.name,-11);
        WriteFString(A[i]^.ext,-6);
        WriteFString(A[i]^.size,12);
        WriteFString(A[i]^.date,10);
        WriteFString(A[i]^.time,8); WriteLn
  END
END WriteArray;

PROCEDURE WriteFString (s: ARRAY OF CHAR; f: INTEGER);
(*      Write string "s" formated in a field of size f.
        IF f < 0  string is left justified
        IF f > 0  string is right justified
        IF Length(s) > f  string is truncated
        padding is done with blanks
*)
  VAR i, n: INTEGER;
       c   : CHAR;
BEGIN
  n:= Length(s);
  IF f > 0 THEN FOR i:= 1 TO f-n DO Write(' ') END END;
  i:= 0;
  REPEAT c:= s[i]; Write(c); INC(i)
  UNTIL (i >= n) OR (i >= ABS(f));
  IF f < 0 THEN FOR i:= 1 TO -f-n DO Write(' ') END END
END WriteFString;

PROCEDURE StringComp (s1, s2: ARRAY OF CHAR): BOOLEAN;
(* returns s1 < s2 *)
  VAR i, max : CARDINAL;
BEGIN
  i:= 0; max:= HIGH(s1);
  WHILE (i < max) & (s1[i] = s2[i]) DO
        IF s1[i] = EOS
         THEN RETURN FALSE                          (* s1 = s2 *)
         ELSE INC(i)
        END
  END;
  RETURN s1[i] < s2[i]
END StringComp;

BEGIN
  comp:= compName                                   (* default *)
END SortElemType.
```

SORTTEST.MOD From "Programming Project: Crafting Reusable Software in Modula-2" by Hanna Oktaba and René Berber, BYTE, September 1987.

```
(*****
 *
 *      Test of generic sorting routine
 *
 *****)
```

```
MODULE SortTest;

      FROM InOut IMPORT OpenInput, CloseInput, WriteString, WriteLn, ReadCard,
                        OpenOutput, CloseOutput;
      FROM Sort IMPORT Qsort;
      FROM SortElemType IMPORT ElemType, select, optionMenu,
                               ReadArray, WriteArray;
      CONST
           N = 200;

VAR
  a : ARRAY [1..N] OF ElemType;
  n : CARDINAL:                          (* actual number of elements in "a" *)
  opt : CARDINAL;

BEGIN
  WriteString("Which file contains the data ? ");
  OpenInput("");
  n:= ReadArray(a);
  CloseInput;
  optionMenu;
  WriteString("Sort by ? ");
  ReadCard(opt); WriteLn;
  select(opt);
  Qsort(a,n);
  WriteLn; WriteString("Output file [ Esc for console ] ? ");
  OpenOutput("");
  WriteArray(a,n);
  CloseOutput
END SortTest.
```

SORTELEM.DEF From "Programming Project: Crafting Reusable Software in Modula-2" by Hanna Oktaba and René Berber, BYTE, September 1987.

```
DEFINITION MODULE SortElemType;
(*      This module is intended to describe the elements to be sorted
 *      as an abstract data type.
 *)

        EXPORT QUALIFIED ElemType, compare, select, optionMenu,
                                   ReadArray, WriteArray;
TYPE
        ElemType;                                                    (* pointer to data element *)

PROCEDURE compare (x, y: ElemType): BOOLEAN;
        (* compare(x,y) implements: x < y
                        defined as NOT (y <= x), for ascending order;
                        and if descending order is desired
        compare(x,y) should implement: x > y
                        defined as NOT (x <= y);
        where "<=" denotes a binary relation that must satisfy
        the total order properties:
          1. x <= x
          2. x <= y AND y <= x   ==>  x = y
          3. x <= y AND y <= z   ==>  x <= z
          4. x <= y OR y <= x   for every x, y
         *)

PROCEDURE select (option: CARDINAL);
        (* input:                  - a number denoting the requested option
           output:          - the exported compare procedure gets assigned to one
                                 of the comparison procedures.
                                   - the option should be valid; otherwise a default
                                 may be used
         *)

PROCEDURE optionMenu;
        (* output:          - displays on the screen the available options. *)
```

continued

```
PROCEDURE ReadArray(VAR A: ARRAY OF ElemType): CARDINAL;
        (* input:                  - an array of pointers, declared by the user module.
           output:          - the array is filled with pointers to the memory used by the elements
                                  read, and the number of them is returned.
           errors:          - can run out of memory.
                            NOTE: If the file contains more elements than those that can be stored in the array, they are ignored.
         *)

PROCEDURE WriteArray(A: ARRAY OF ElemType; n: CARDINAL) ;
        (* input:                  - an array of pointers, and the number of elements.
           output:          - the elements are written to current output of InOut.
         *)

END SortElemType.
```

SORT.MOD From "Programming Project: Crafting Reusable Software in Modula-2" by Hanna Oktaba and René Berber, BYTE, September 1987.

```
IMPLEMENTATION MODULE Sort;

        FROM SortElemType IMPORT ElemType, compare;

PROCEDURE Qsort (VAR A: ARRAY OF ElemType; N: CARDINAL);

  PROCEDURE sort (l, r: INTEGER);          (* N. Wirth '86 *)
        VAR i, j : INTEGER;
            x, w : ElemType;
  BEGIN
        i:= l; j:= r;
        x:= A[(l+r) DIV 2];
        REPEAT
          WHILE compare(A[i],x) DO INC(i) END;
          WHILE compare(x,A[j]) DO DEC(j) END;
          IF i <= j
            THEN w:= A[i]; A[i]:= A[j]; A[j]:= w;
              INC(i); DEC(j)
          END;
        UNTIL i > j;
        IF l < j THEN sort(l,j) END;
        IF i < r THEN sort(i,r) END
  END sort;

BEGIN
        IF N > HIGH(A)+1 THEN N:= HIGH(A)+1 END;
        sort(0,N-1)
END Qsort;

END Sort.
```

ADD-PATT.C From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
/*
ADD-PATT ADDS A PATTERN TO THE BAM MATRIX XTY

COPYRIGHT (C) 1987, JOEL S. DAVIS. AFTER BYTE PUBLICATION, APPROVED FOR
NONCOMMERCIAL USE ONLY.
*/
#include "STRUCT.H"
#include "EXT.H"
add_patt(an,bn)
int *an,*bn;
{
      int i,j;
```

```
/*      MAKE VECTORS BIPOLAR */
        for(i=0;i<*an;i++){
                if(a[i]<=0){
                   x[i] = -1;
                }else{
                   x[i] = 1;
                }
        }

        for(j=0;j<*bn;j++){
                if(b[j]<=0){
                   y[j] = -1;
                }else{
                   y[j] = 1;
                }
        }

/*      UPDATE XTY */
        for(i=0;i<*an;i++){
                for(j=0;j<*bn;j++){
                   xty[i][j] += x[i]*y[j];
                }
        }

/*      SIGNAL COMPLETION */
        putchar(BELL);
}
```

SORT.DEF From "Programming Project: Crafting Reusable Software in Modula-2" by Hanna Oktaba and René Berber, BYTE, September 1987.

```
DEFINITION MODULE Sort;

        FROM SortElemType IMPORT ElemType, compare;

(* Module SortElemType is used to define the kind of element to be sorted *)

        EXPORT QUALIFIED Qsort;

PROCEDURE Qsort (VAR A: ARRAY OF ElemType; N: CARDINAL);
(* input:                - array of pointers to elements, and number of elements
 *                           [ N <= HIGH(A)+1 ].
 * output:          -the array of pointers is rearranged so they point to the
 *                           elements in sorted order.
 * requires that ElemType has a total order relation named "compare".
 *)

END Sort.
```

README.BAM From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
TO RUN BAM:
          FILES BAM.COM, BAM.PAS, XFACE.INC, PAT1(NOT NECESSARY)
          README.BAM - this file
          > BAM

          ** RUNS THE PROGRAM **

          SYSTEM REQUIREMENTS: COLOR MONITOR (CGA) OR Mono Graphics
                    TURBO PASCAL (FOR EDITING)

          STATUS LINE: PRESS A, S, H, OR Q
```

continued

```
          ANSWER YES/NO QUESTIONS WITH Y OR N <RETURN>.

          PAT1 is a sample pattern file.

code 15,712 bytes
data 49,424 bytes


FFI:      Dr. Rod Taber
          General Dynamics
          Electronics Division Mail Zone 7202-K
          Box 85310
          San Diego, CA 92138


Mail without Mail Zone takes 3 months.
```

AWAIT.C From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
/*
AWAIT ASKS THE USER FOR ANOTHER KEY ENTRY AFTER N RETURNS
*/
await(im)
int im;
{
int i;

     for(i=0;i<im;i++){
       printf("\n");
     }
     printf("Press any key to continue: ");
     getchar();
}
```

ASYNCH.C From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
/*
ASYNCH ASYNCHRONOUSLY UPDATES THE BAM

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NONCOMMERCIAL USE ONLY.
*/
#include "STRUCT.H"
#include "EXT.H"
asynch(axn,ayn,bxn,byn,an,bn,n_asyn)
int *axn,*ayn,*bxn,*byn,*an,*bn,n_asyn;
{
int i,j,k,l,m,n,index,iter,sum;
int seed;
char buf[9];
double x,frand( );

/* GET A RANDOM NUMBER SEED FROM THE SYSTEM CLOCK */
/* READ THE CLOCK */
     times(buf);

/* GENERATE THE SEED INTEGER */
     seed = (int) (buf[7] - '0');
     seed += seed + 10 * ((int) ((buf[6] - '0')));
     seed += seed + 60 * ((int) ((buf[4] - '0')));
     seed += seed + 600 * ((int) ((buf[3] - '0')));
     srand(seed);
```

```
/* GO THROUGH 10 ITERATIONS */
    iter = 10;
    for(k=0;k<iter;k++){
/*      UPDATE N_ASYN NEURONS */
        for(n=0;n<n_asyn;n++){
            sum = 0;
/*          PROCESS B VECTOR NEURON */
/*          WHICH NEURON DO I UPDATE THIS TIME ? */
            x = (double) *bn;
            x *= frand( );
            x += 0.5;
            j = (int) x;

/*          APPLY ALL A VECTOR INPUTS */
            for(i=0;i<*an;i++){
                sum += a[i] * xty[i][j];
            }

/*          NOW DO THRESHOLDING */
            if(sum>0){
                b[j] = 1;
            }else if(sum<0){
                b[j] = 0;
            }else{
/*              RETAIN VALUE */
                continue;
            }
      }

        vec_show(axn,ayn,bxn,byn);

/*      NOW IN REVERSE TO PROCESS A VECTOR NEURONS */
/*      UPDATE N_ASYN NEURONS */
        for(n=0;n<n_asyn;n++){
            sum = 0;
/*          PROCESS B VECTOR NEURON */
/*          WHICH NEURON DO I UPDATE THIS TIME ? */
            x = (double) *an;
            x *= frand( );
            x += 0.5;
            i = (int) x;

/*          FOR EACH A VECTOR NEURON, APPLY ALL B VECTOR INPUTS */
            for(j=0;j<*bn;j++){
                sum += b[j] * xty[i][j];
            }
/*          NOW DO THRESHOLDING */
            if(sum>0){
                a[i] = 1;
            }else if(sum<0){
                a[i] = 0;
            }else{
/*          RETAIN VALUE */
                continue;
            }
        }

        vec_show(axn,ayn,bxn,byn);
    }
}
```

SIEVE386.ASM Accompanies "The Kaypro 386" by Ray Duncan, BYTE, September 1987.

```
Title   "Eratosthenes Sieve for 80386"
Name    Sieve
Page    50,132

;
```

continued

```
; Eratosthenes Sieve for 80386 32-bit protected mode
; Implemented by Ray Duncan, April 1987
; After Gilbreath, BYTE, September 1981 and January 1983
;
; Here is the MAKE file for this program:
;
; sieve386.obj : sieve386.asm
;  386asm sieve386
;
; sieve386.exe : sieve386.obj
;  386link sieve386 start386 -exe sieve386 -map sieve386
;
; To run the program with Phar Lap DOS|EXTENDER:
; -C>RUN386 SIEVE386
;

niter   equ     100                     ; number of iterations
asize   equ     8190                    ; size of array "flags"

cr      equ     0dh                     ; ASCII carriage return
lf      equ     0ah                     ; ASCII linefeed

stdin   equ     0                       ; handle for standard input
stdout  equ     1                       ; handle for standard output

_TEXT   segment para public use32 'CODE'

        assume cs:_TEXT,ds:_DATA,es:_DATA

        public _start_                  ; magic name for RUN386 entry


_start_ proc    near

        xor     edx,edx                 ; convert number of iterations
        mov     eax,niter               ; for output
        mov     ecx,10
        mov     esi,offset msg1a+3
        call    binasc

        mov     edx,offset msg1         ; display message
        mov     ecx,msg1_len            ; "Starting N iterations of Sieve"
        call    pmsg

        call    getmsec                 ; get current time in msec
        push    eax                     ; and save it...

        mov     counter,niter           ; initialize iterations counter

sieve1:                                 ; a sieve iteration starts here...
        mov     edi,offset flags        ; initialize flags array
        mov     ecx,asize               ; to all bytes = TRUE
        mov     al,1
        cld
        rep stosb

        xor     esi,esi                 ; ESI = index to flags array
        xor     edi,edi                 ; EDI = primes counter

sieve2:                                 ; main loop of sieve
        test    byte ptr flags[esi],1   ; is this a prime?
        jnz     short sieve4            ; jump if prime

sieve3: inc     esi                     ; bump to next slot in "flags"
        cmp     esi,asize
        jle     sieve2                  ; loop until array exhausted

        dec     counter                 ; count off sieve iterations
        jnz     sieve1                  ; jump, another iteration needed.
        jmp     sieve7                  ; jump, all iterations finished.

sieve4:                                 ; prime found, zap its multiples
        mov     ebx,esi                 ; copy i
        mov     edx,ebx                 ; EDX = prime = i + i + 3
        add     edx,edx
        add     edx,3
```

```
            xor     al,al
            jmp     short sieve6
sieve5:     mov     byte ptr flags[ebx],al; zero this multiple

sieve6:     add     ebx,edx             ; find next multiple of prime
            cmp     ebx,asize           ; have we exhausted the array?
            jle     sieve5              ; not yet, zap it
            inc     edi                 ; count primes and try next
            jmp     sieve3

sieve7:     call    getmsec             ; all done, get current time
            push    eax

            mov     eax,edi             ; convert number of primes
            mov     edx,0               ; found on last iteration
            mov     ecx,10
            mov     esi,offset msg2a+4
            call    binasc

            mov     edx,offset msg2     ; display "Number of primes: "
            mov     ecx,msg2_len
            call    pmsg

            pop     eax                 ; calculate total elapsed msec.
            pop     ebx
            sub     eax,ebx

            mov     edx,0               ; divide by number of iterations
            mov     ecx,niter           ; to get msec per iteration
            idiv    ecx

            mov     edx,0               ; convert msec to ASCII
            mov     ecx,10
            mov     esi,offset msg3a+4
            call    binasc

            mov     edx,offset msg3     ; display "Elapsed time:"
            mov     ecx,msg3_len
            call    pmsg

            mov     ax,04C00h           ; final exit, return code = 0
            int     21H

_start_     endp

getmsec     proc    near                ; Return EAX = current time in msec.

            mov     ah,2ch              ; read time
            int     21h
            movzx   eax,ch              ; EAX := hours
            imul    eax,60              ; hours -> minutes
            and     ecx,0ffh            ; isolate system minutes
            add     eax,ecx             ; and find total minutes
            imul    eax,60              ; minutes -> seconds
            movzx   ecx,dh              ; isolate system seconds
            add     eax,ecx             ; and find total seconds
            and     edx,0ffh            ; isolate hundredths
            imul    eax,100             ; seconds -> hundredths
            add     eax,edx             ; find total hundredths
            imul    eax,10              ; hundredths -> msec
            ret

getmsec     endp

;
; BINASC: Convert 64-bit binary value to ASCII string.
;
; Call with EDX:EAX = signed 64-bit value
;           ECX     = radix
;           DS:ESI  = last byte of area to store resulting string
;                     (make sure enough room is available to store
;                     the string in the radix you have selected.)
;
; Destroys EAX, EBX, ECX, EDX, and ESI.
;
```

continued

```
binasc proc   near                    ; convert EDX:EAX to ASCII.

       mov    byte ptr [esi],'0'      ; force storage of at least one digit.
       or     edx,edx                 ; test sign of 64-bit value,
       pushf                          ; and save sign on stack.
       jns    bin1                    ; jump if it was positive.
       not    edx                     ; negative, take 2's complement
       not    eax                     ; of the value.
       add    eax,1
       adc    edx,0
bin1:                                 ; divide 64-bit value by the radix
                                      ; to extract next digit for the
                                      ; forming string.
       mov    ebx,eax                 ; is the value zero yet?
       or     ebx,edx
       jz     bin3                    ; yes, we are done converting.
       call   divide                  ; no, divide by radix.
       add    bl,'0'                  ; convert remainder to ASCII digit.
       cmp    bl,'9'                  ; might be converting hex ASCII,
       jle    bin2                    ; jump if in range 0-9,
       add    bl,'A'-'9'-1            ; correct it if in range A-F.
bin2:  mov    [esi],bl                ; store this character into string.
       dec    esi                     ; back up through string,
       jmp    bin1                    ; and do it again.
bin3:                                 ; restore sign flag,
       popf                           ; was original value negative?
       jns    bin4                    ; no, jump
       mov    byte ptr [esi],'-'      ; yes, store sign into output string.
bin4:  ret                            ; back to caller.

binasc endp

;
; General-purpose 64-bit by 32-bit unsigned divide.
; This must be used instead of the plain machine unsigned divide
; for cases where the quotient may overflow 32 bits. If called with
; zero divisor, this routine returns the dividend unchanged and gives
; no warning.
;
; Call with EDX:EAX = 64-bit dividend
;          ECX      = divisor
;
; Returns  EDX:EAX = quotient
;          EBX      = remainder
;          ECX      = divisor (unchanged)
;
divide   proc   near                  ; Divide EDX:EAX by ECX

         jecxz  div1                  ; exit if divide by zero
         push   eax                   ; 0:dividend_upper/divisor
         mov    eax,edx
         xor    edx,edx
         div    ecx
         mov    ebx,eax               ; EBX = quotient1
         pop    eax                   ; remainder1:dividend_lower/divisor
         div    ecx
         xchg   ebx,edx               ; EDX:EAX = quotient1:quotient2

div1:    ret                          ; EBX = remainder2

divide   endp

pmsg     proc   near                  ; print a message on std output
                                      ; call with DS:EDX = address
                                      ;           ECX    = length
         mov    ah,40h
         mov    bx,stdout
         int    21h
         ret
pmsg     endp

_TEXT    ends

_DATA    segment para public use32 'DATA'
```

```
flags     db      asize+1 dup (?)
counter   dd      ?                       ; sieve iteration counter

msg1      db      cr,lf,'Starting '
msg1a     db      '   iterations of Sieve...',cr,lf
msg1_len  equ $-msg1


msg2      db      cr,lf,'Primes found: '
msg2a     db      '   ',cr,lf
msg2_len  equ $-msg2

msg3      db      cr,lf,'Elapsed time: '
msg3a     db      '   msec. per iteration',cr,lf
msg3_len  equ $-msg3

_DATA     ends
_STACK    segment byte stack use32 'stack'
          db      4096 dup (?)
_STACK    ends

          end
```

GET_MTX.C From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
/*
GET_MTX GETS THE VALUES FOR AN XTY MEMORY MATRIX FROM MASS STORAGE

COPYRIGHT (C) 1987, JOEL S. DAVIS. AFTER BYTE PUBLICATION, APPROVED FOR NONCOMMERCIAL USE ONLY.
*/
#include <c:\cware\stdio.h>
#include <struct.h>
#include <ext.h>
get_mtx(axn,ayn,bxn,byn,an,bn)
int *axn,*ayn,*bxn,*byn,*an,*bn;
{
   int i,j,total;
   FILE *f3,*fopen( );
   char fname[40];

   for(;;){
      for(i=0;i<40;i++) fname[i] = 0;

      cls0( );
      printf("\n\n\nPlease enter name of file containing memory values");
      printf(   "\nyou wish to restore: ");
      scanf("%s",fname);

/*      OPEN INPUT FILE */
      if((f3=fopen(fname,"r"))==NULL){
        printf("\nCan't open INPUT FILE %s\n",fname);
        printf("\nTry again! Hit [ENTER] to continue... ");
        getchar( );
      }else{
        break;
      }
   }

/*  CLEAR THE BAM */
   clearbam( );

/*  READ HORIZONTAL AND VERTICAL DIMENSIONS OF A AND B ARRAYS */
   fscanf(f3,"%d %d %d %d",axn,ayn,bxn,byn);
   printf("\n\n Reading A array %d x %d and B array %d x %d",
          *axn,*ayn,*bxn,*byn);

   *an = (*axn) * (*ayn);
   *bn = (*bxn) * (*byn);
   total = (*an) * (*bn);
```

continued

```
    printf("\n%dx%d xTy -> %d lines to be read!",*an,*bn,total);
    printf("\nDepending upon your machine, this could take a minute or so...");

    for(i=0;i<*an;i++){
       for(j=0;j<*bn;j++){
         fscanf(f3,"%d",&xty[i][j]);
       }
    }
    fclose(f3);

}
```

PAT1 From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
4
4
8
6
10
1111111110000001111111110000001
0001110000000011000000001100000000110000000011000000001111000
1111111100011000000110000000011000
0111111110110000001100000000110001111110011100000011111111111
1111111110000001100000011111111
1100011000110001100011000110001111111111000001100000000011000
1110011110111101100110011000001
1111111111000000001100000011100000111000001110000011100000000
```

EXT.H From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
/*
BAM PARAMETER ARRAYS

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*/

extern int a[DIMEN1],b[DIMEN2],x[DIMEN1],y[DIMEN2],xty[DIMEN1][DIMEN2];
extern int newvec1[DIMEN1],newvec2[DIMEN2];
```

BAM.C From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
/*
PROGRAM BAM
================================================================================
BY
JOEL S. DAVIS
1310 CONSTITUTION COURT, NE
ALBUQUERQUE, NM 87112
================================================================================

THIS PROGRAM IS A SIMPLE IMPLEMENTATION OF THE BIDIRECTIONAL CORRELATION MEMORY ALGORITHM DEVELOPED BY BART KOSKO. THE SOURCE CODE
IS WRITTEN FOR DESMET C BY CWARE RUNNING UNDER MS-DOS.

IT COMBINES FEATURES FROM THE DUANE DESIENO BAM PROGRAM, WRITTEN IN BASIC, AND MY OWN ASSOC AND BASSOC PROGRAMS, WRITTEN IN C.

THIS VERSION IS DATED: 7-AUGUST-1987

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*/
```

```
#include <\cware\stdio.h>
#include <\cware\math.h>
#include <struct.h>
int a[DIMEN1],b[DIMEN2],x[DIMEN1],y[DIMEN2],xty[DIMEN1][DIMEN2];
int newvec1[DIMEN1],newvec2[DIMEN2];

main(argc,argv)
int argc;
char **argv;
{
int i,j,k,l,m,n,d2;
int op;
int axn,ayn,bxn,byn,n_asyn,pct_noise,an,bn;

/*      INITIALIZE DIMENSIONS */
        clearbam();
        initial(&axn,&ayn,&bxn,&byn,&an,&bn,&n_asyn,&pct_noise);

/*      INTRODUCTION */
        intro();

/*      PRESENT MAIN MENU */
        for(;;){
              op = mainmenu();

              if(op==1){
/*                 NEW PROGRAM PARAMETERS */
                   new_parm(&axn,&ayn,&bxn,&byn,&an,&bn,&n_asyn,&pct_noise);

              }else if(op==2){
/*                 CLEAR VECTORS AND BAM */
                   clearbam();

              }else if(op==3){
/*                 LOAD THE MEMORY MATRIX */
                   get_mtx(&axn,&ayn,&bxn,&byn,&an,&bn);

              }else if(op==4){
/*                 SAVE THE MEMORY MATRIX */
                   save_mtx(&axn,&ayn,&bxn,&byn,&an,&bn);

              }else if(op==5){
/*                 OPERATE ON MEMORY AND RUN BAM */
                   run_bam(&axn,&ayn,&bxn,&byn,&an,&bn,n_asyn,pct_noise);

              }else if(op==6){
/*                 QUIT */
                   break;
              }
        }
}
```

CLEARBAM.C From "Constructing an Associative Memory" by Bart Kosco, BYTE, September 1987.

```
/*
CLEARBAM CLEARS ALL BAM VECTORS AND THE XTY MATRIX

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*/
#include <STRUCT.H>
#include <EXT.H>

clearbam()
{
int d2;

/* SET MATRICES TO ZERO */
   zero_1d(a,DIMEN1);
   zero_1d(b,DIMEN2);
```

continued

```
    zero_1d(x,DIMEN1);
    zero_1d(y,DIMEN2);
    zero_1d(newvec1,DIMEN1);
    zero_1d(newvec2,DIMEN2);

/* NOW 2-DIMENSIONAL VECTORS, WHICH WILL BE TREATED LIKE 1-D VECTORS */
    d2 = DIMEN1 * DIMEN2;
    zero_1d(xty,d2);
}
```

SIEVE86.ASM Accompanies "The Kaypro 386" by Ray Duncan, BYTE, September 1987.

```
        Title   "Eratosthenes Sieve for 80x86 Real Mode"
        Name    Sieve
        Page    50,132

;
; Eratosthenes Sieve for 80x86 Real Mode
; Implemented by Ray Duncan, April 1987
; After Gilbreath, BYTE, September 1981 and January 1983
;

niter   equ     100                     ; number of iterations
asize   equ     8190                    ; size of array "flags"

cr      equ     0dh                     ; ASCII carriage return
lf      equ     0ah                     ; ASCII linefeed

stdin   equ     0                       ; handle for standard input
stdout  equ     1                       ; handle for standard output

_TEXT   segment para public 'CODE'

        assume cs:_TEXT,ds:_DATA,es:_DATA

sieve   proc    near

        mov     ax,seg _DATA
        mov     ds,ax
        mov     es,ax

        mov     dx,0                    ; convert number of iterations
        mov     ax,niter
        mov     cx,10
        mov     si,offset msg1a+3
        call    binasc

        mov     dx,offset msg1          ; display message
        mov     cx,msg1_len             ; "Starting N iterations of Sieve"
        call    pmsg

        call    getmsec                 ; get current time in msec
        push    dx                      ; and save it ...
        push    ax

        mov     counter,niter           ; initialize iterations counter

sieve1:                                 ; a sieve iteration starts here...
        mov     di,offset flags         ; initialize flags array
        mov     cx,asize                ; to all bytes = TRUE
        mov     al,1
        cld
        rep stosb

        xor     si,si                   ; SI = index to flags array
        xor     di,di                   ; DI = primes counter

sieve2:                                 ; main loop of sieve
        test    byte ptr flags[si],1    ; is this a prime?
        jnz     short sieve4            ; jump if prime
```

```
sieve3:  inc     si                      ; bump to next slot in "flags"
         cmp     si,asize                ; are we done?
         jle     sieve2                  ; jump to test another

         dec     word ptr counter        ; more iterations?
         jnz     sieve1                  ; jump, another iteration needed
         jmp     sieve7

sieve4:                                  ; prime found, zap its multiples
         mov     bx,si                   ; copy i
         mov     dx,bx                   ; DX = prime = i + i + 3
         add     dx,dx
         add     dx,3
         xor     al,al
         jmp     short sieve6

sieve5:  mov     byte ptr flags[bx],al   ; zero this multiple

sieve6:  add     bx,dx                   ; find next multiple of prime
         cmp     bx,asize                ; have we exhausted the array?
         jle     sieve5                  ; not yet, zap it
         inc     di                      ; count primes and try next
         jmp     sieve3

sieve7:                                  ; done with all iterations...
         call    getmsec                 ; get current time
         push    dx                      ; and save it...
         push    ax

         mov     ax,di                   ; convert number of primes
         mov     dx,0
         mov     cx,10
         mov     si,offset msg2a+4
         call    binasc

         mov     dx,offset msg2          ; display "Number of primes:"
         mov     cx,msg2_len
         call    pmsg

         pop     ax                      ; stop time: low word
         pop     dx                      ;            high word

         pop     bx                      ; start time: low word
         pop     cx                      ;             high word

         sub     ax,bx                   ; DX:AX = stop - start
         sbb     dx,cx

         mov     cx,niter                ; divide by number of iterations
         idiv    cx

         mov     dx,0                    ; convert msec to ASCII
         mov     cx,10
         mov     si,offset msg3a+4
         call    binasc

         mov     dx,offset msg3          ; display "Elapsed time:"
         mov     cx,msg3_len
         call    pmsg

         mov     ax,04C00h               ; exit to DOS with
         int     21H                     ; return code = 0

sieve    endp

getmsec  proc    near                    ; DX:AX := current time in msec.

         mov     ah,2ch                  ; read time from MS-DOS
         int     21h
         push    dx                      ; save seconds, hundredths
         mov     al,0h                   ; AX := hours
         cbw
         mov     bx,60                   ; hours -> minutes
         imul    bx
         xor     0h,0h                   ; isolate system minutes
```

continued

```
        add     ax,cx                   ; and find total minutes
        mov     bx,60                   ; minutes -> seconds
        imul    bx
        pop     cx                      ; recover seconds, hundredths
        mov     bl,ch                   ; get seconds
        xor     bh,bh
        add     ax,bx                   ; find total seconds
        adc     dx,0                    ; carry if necessary
        xor     ch,ch                   ; save centisec.
        mov     bp,cx
                                        ; total seconds * 100 the hard way
        mov     bx,ax                   ; double multiply * 10
        mov     cx,dx
        add     ax,ax                   ; * 2
        adc     dx,dx
        add     ax,ax                   ; * 4
        adc     dx,dx
        add     ax,bx                   ; * 5
        adc     dx,cx
        add     ax,ax                   ; * 10
        adc     dx,dx

        mov     bx,ax                   ; double multiply * 10
        mov     cx,dx
        add     ax,ax                   ; * 2
        adc     dx,dx
        add     ax,ax                   ; * 4
        adc     dx,dx
        add     ax,bx                   ; * 5
        adc     dx,cx
        add     ax,ax                   ; * 10
        adc     dx,dx

        add     ax,bp                   ; add in hundredths of seconds
        adc     dx,0
                                        ; now convert total to msec.
        mov     bx,ax                   ; double multiply * 10
        mov     cx,dx
        add     ax,ax                   ; * 2
        adc     dx,dx
        add     ax,ax                   ; * 4
        adc     dx,dx
        add     ax,bx                   ; * 5
        adc     dx,cx
        add     ax,ax                   ; * 10
        adc     dx,dx

        ret                             ; return DX:AX = msec.

getmsec endp

; BINASC: Convert 32-bit binary value to ASCII string.
;
; Call with DX:AX = signed 32-bit value
;           CX    = radix
;           SI    = last byte of area to store resulting string
;                   (make sure enough room is available to store the string in the radix you have selected.)
;
; Destroys AX, BX, CX, DX, and SI.
;

binasc  proc    near                    ; convert DX:AX to ASCII.

        mov     byte ptr [si],'0'       ; force storage of at least one digit.
        or      dx,dx                   ; test sign of 32-bit value,
        pushf                           ; and save sign on stack.
        jns     bin1                    ; jump if it was positive.
        not     dx                      ; negative, take 2's complement
        not     ax                      ; of the value.
        add     ax,1
        adc     dx,0
bin1:                                   ; divide 32-bit value by radix
                                        ; to extract next digit for the
                                        ; forming string.
        mov     bx,ax                   ; is the value zero yet?
        or      bx,dx
```

```
        jz      bin3                    ; yes, we are done converting.
        call    divide                  ; no, divide by radix.
        add     bl,'0'                  ; convert remainder to ASCII digit.
        cmp     bl,'9'                  ; might be converting to hex ASCII,
        jle     bin2                    ; jump if in range 0-9,
        add     bl,'A'-'9'-1            ; correct it if in range A-F.
bin2:   mov     [si],bl                 ; store this character into string.
        dec     si                      ; back up through string,
        jmp     bin1                    ; and do it again.
bin3:                                   ; restore sign flag,
        popf                            ; was original value negative?
        jns     bin4                    ; no, jump
        mov     byte ptr [si],'-'       ; yes, store sign into output.
bin4:   ret                             ; back to caller.

binasc  endp

;
; General-purpose 32-bit by 16-bit unsigned divide.
; This must be used instead of the plain machine unsigned divide for cases where the quotient may overflow 16 bits
; (for example, dividing 100,000 by 2). If called with a zero divisor, this routine returns the dividend unchanged
; and gives no warning.
;
; Call with DX:AX = 32-bit dividend
;          CX     = divisor
;
; Returns  DX:AX = quotient
;          BX     = remainder
;          CX     = divisor (unchanged)
;

divide  proc    near                    ; Divide DX:AX by CX

        jcxz    div1                    ; exit if divide by zero
        push    ax                      ; 0:dividend_upper/divisor
        mov     ax,dx
        xor     dx,dx
        div     cx
        mov     bx,ax                   ; BX = quotient1
        pop     ax                      ; remainder1:dividend_lower/divisor
        div     cx
        xchg    bx,dx                   ; DX:AX = quotient1:quotient2

div1:   ret                             ; BX = remainder2

divide  endp

pmsg    proc    near                    ; print a message on std output
                                        ; call with DS:EDX = address
                                        ;           ECX    = length
        mov     ah,40h
        mov     bx,stdout
        int     21h
        ret

pmsg    endp

_TEXT   ends

_DATA   segment para public 'DATA'

flags   db      asize+1 dup (?)
counter dw      ?

msg1    db      cr,lf,'Starting '
msg1a   db      '       iterations of Sieve...',cr,lf
msg1_len equ $-msg1

msg2    db      cr,lf,'Primes found: '
msg2a   db      '       ',cr,lf
msg2_len equ $-msg2

msg3    db      cr,lf,'Elapsed time: '
msg3a   db      '       msec. per iteration',cr,lf
msg3_len equ $-msg3
```

continued

```
_DATA   ends

_STACK  segment byte stack 'stack'
        db      4096 dup (?)
_STACK  ends

        end     sieve
```

TURBFLOP.PRO Contributed by Alex Lane. From "ALS Prolog," BYTE, September 1987.

```
/* Floating-Point Test Program  */
/*                              */
/* written in Turbo Prolog      */
/* 6-10-87  a.lane              */
/*                              */
/* result for 5000 repetitions: */
/*     30 seconds               */

predicates
        float_point
        time_1( integer )
        cycle( integer, real, real, real )
        calc( real, real, real, real )
goal
        float_point.
clauses
        float_point :-
                write( "Enter number of repetitions: " ),
                readint( Iters ),
                time_1( Start ),
                cycle( Iters, 1.0, 2.71828, 3.14159 ),
                time_1( Finish ),
                Overall = Finish - Start,
                write( "Time is " ),
                write( Overall ),nl.

        calc( C,CF,A,B ) :-
                C1 = C * A,
                C2 = C1 * B,
                C3 = C2 / A,
                CF = C3 / B.

        cycle( 0,C,_,_ ) :-
                write( "C is " ),
                write( C ),nl.

        cycle( N,C,A,B ) :-
                calc(C,CF,A,B),
                N1 = N - 1,
                cycle(N1,CF,A,B).

        time_1( Time ) :-
                /* quick and dirty; won't work across midnight */
                /* and ignores hundreths of a second           */
                time( H,M,S,_ ),
                Time = S + 60 * (M + 60 * H).
```

KAREX2.BAS Accompanies the article "Karmarkar's Algorithm" by Andrew M. Rockett and John C. Stevenson, BYTE, September 1987.

```
100 ' ------------------------------------------------------------------------------------------------------------------------
101 '
102 ' KAREX2.BAS is a Microsoft BASIC Release 5 program
103 ' that solves EXAMPLE 2 of the article
104 '
105 '            KARMARKAR'S ALGORITHM
```

```
106 '
107 ' by Andrew M. Rockett and John C. Stevenson
108 '
109 ' This program was written by Andrew M. Rockett
110 '
111 ' ------------------------------------------------------------------------------------------------------------------------
200 '
202 ' N is the number of unknowns and K is the number of equations
204 '
206 N = 8 : K = 4
208 '
210 K1 = K + 1 : K2 = 2*K1
212 DIM AO(N), XOLD(N), XNEW(N), CC(N), CP(N),
    A(K,N), B(K1,N), B1(K1,K2), B2(N,K1), B3(N,N)
214 FOR C = 1 TO N : AO(C) = 1/N : XNEW(C) = AO(C) :
    NEXT C
216 '
218 ' T is the tolerance
220 '
222 T = .001
224 '
226 ' ALPHA is usually set equal to 1/4 ...
228 '
230 ALPHA = .25
232 '
234 ITERATION = 0
236 '
238 ' Data for constraint matrix A
240 '
242 DATA 1, 0, 1, 0, 0, 0, 1, -3
244 DATA 1, 0, 0, -1, 0, 0, 2, -2
246 DATA 0, 1, 0, 0, 1, 0, 3, -5
248 DATA 0, 1, 0, 0, 0, -1, 4, -4
250 '
252 FOR R = 1 TO K : FOR C = 1 TO N : READ A(R,C) :
    NEXT C : NEXT R
254 '
256 ' Data for objective function CC
258 '
260 DATA 0, 0, 0, 0, 0, 0, 1, 0
262 '
264 FOR C = 1 TO N : READ CC(C) : NEXT C
266 '
268 V = 0 : FOR C=1 TO N : V = V + CC(C)*AO(C) :
  NEXT C : VNEW = V
270 '
272 ' Main iteration process is the same as in KAREX1.BAS ...
274 '
300 WHILE VNEW/V > T
301 PRINT USING "###";ITERATION;:
    FOR C=1 TO N:PRINT USING "###.####";XNEW(C); :
    NEXT C : PRINT USING "####.########";VNEW/V
302 ITERATION = ITERATION + 1
303 FOR C = 1 TO N : XOLD(C) = XNEW(C) : NEXT C
304 FOR R=1 TO K:FOR C=1 TO N:B(R,C)=A(R,C)*XOLD(C):
    NEXT C:NEXT R
305 FOR C=1 TO N:B(K1,C)=1:NEXT C
306 FOR R=1 TO K1 : FOR C=1 TO K2 : B1(R,C)=0 :
    NEXT C : NEXT R
307 FOR R=1 TO N : FOR C=1 TO K1 : B2(R,C)=0 :
    NEXT C : NEXT R
308 FOR R=1 TO N : FOR C=1 TO N : B3(R,C)=0 :
    NEXT C : NEXT R
309 FOR C=1 TO N : CP(C) = 0 : NEXT C
310 FOR R=1 TO K1:FOR C=1 TO K1:
    FOR I=1 TO N:B1(R,C)=B1(R,C)+B(R,I)*B(C,I):
      NEXT I:
    NEXT C:NEXT R
311 FOR I = 1 TO K1 : B1(I,I+K1)=1 : NEXT I
312 FOR R = 1 TO K1
313    IF B1(R,R) <> 0 THEN 318
314     I = R + 1
315     IF I > K1 THEN PRINT 'Error! BBT is SINGULAR!' :
        GOTO 407
```

continued

```
316     IF B1(I,R) = 0 THEN I = I+1 : GOTO 315
317     FOR C = 1 TO K2 : SWAP B1(R,C),B1(I,C) : NEXT C
318    FOR I = R+1 TO K1:Z = B1(I,R)/B1(R,R):
        FOR C=1 TO K2:B1(I,C)=B1(I,C)-Z*B1(R,C):NEXT C:
       NEXT I
319 NEXT R
320 FOR R=K1 TO 2 STEP -1:FOR I = R-1 TO 1 STEP -1:Z = B1(I,R)/B1(R,R):
    FOR C=R TO K2:B1(I,C)=B1(I,C)-Z*B1(R,C):NEXT C:
    NEXT I:NEXT R
321 FOR R=1 TO K1:Z = B1(R,R):
     FOR C=1 TO K2:B1(R,C)=B1(R,C)/Z:NEXT C:
    NEXT R
322 FOR R=1 TO N:FOR C=1 TO K1:
     FOR J=1 TO K1:B2(R,C)=B2(R,C)+B(J,R)*B1(J,C+K1):
      NEXT J:
    NEXT C:NEXT R
323 FOR R=1 TO N:FOR C=1 TO N:
     FOR J=1 TO K1:B3(R,C)=B3(R,C)+B2(R,J)*B(J,C):
      NEXT J:
    NEXT C:NEXT R
324 FOR R = 1 TO N : B3(R,R) = B3(R,R) - 1 : NEXT R
325 FOR R=1 TO N:FOR C=1 TO N:B3(R,C)=-1*B3(R,C):
    NEXT C:NEXT R
326 FOR R=1 TO N:FOR C=1 TO N:B3(R,C)=B3(R,C)*XOLD(C):
    NEXT C:NEXT R
327 FOR R=1 TO N:FOR C=1 TO N:CP(R)=CP(R)+B3(R,C)*CC(C):
    NEXT C:NEXT R
328 AA=0:FOR C=1 TO N : AA = AA + CP(C)*CP(C) : NEXT C
329 AA = SQR(AA) : FOR C=1 TO N : CP(C) = CP(C)/AA :
    NEXT C
330 AA = SQR(N*(N-1))/ALPHA
331 FOR C=1 TO N : XNEW(C) = (AO(C) - CP(C)/AA)*XOLD(C) :
    NEXT C
332 AA=0:FOR C=1 TO N : AA = AA + XNEW(C) : NEXT C
333 FOR C=1 TO N : XNEW(C) = XNEW(C)/AA : NEXT C
334 VNEW=0:FOR C=1 TO N:VNEW=VNEW+CC(C)*XNEW(C):NEXT C
335 WEND
336 '
400 PRINT:PRINT'Tolerance reached: Vnew/Vinitial = ';
     VNEW/V:PRINT
401 PRINT USING "###"; ITERATION; :
    FOR C=1 TO N:PRINT USING "###.####";XNEW(C); : NEXT C :
    PRINT USING "####.#######";VNEW/V
402 '
403 ' Project solution from simplex back to orthant ...
404 '
405 PRINT:FOR C=1 TO N-2:PRINT XNEW(C)/XNEW(N), :
    NEXT C:PRINT
406 '
407 END
```

KAREX1.BAS Accompanies the article "Karmarkar's Algorithm" by Andrew M. Rockett and John C. Stevenson, BYTE, September 1987.

```
100 ' ------------------------------------------------------------------------------------------------------------------------
101 '
102 '  KAREX1.BAS is a Microsoft BASIC Release 5 program that solves EXAMPLE 1 of the article
103 '
104 '
105 '                KARMARKAR'S ALGORITHM
106 '
107 '   by Andrew M. Rockett and John C. Stevenson
108 '
109 'This program was written by Andrew M. Rockett
110 '
111 ' ------------------------------------------------------------------------------------------------------------------------
200 '
202 '  N is the number of unknowns and K is the number of equations
204 '
206 N = 3 : K = 1
208 '
210 K1 = K + 1 : K2 = 2*K1
```

```
212 DIM AO(N), XOLD(N), XNEW(N), CC(N), CP(N), A(K,N), B(K1,N), B1(K1,K2), B2(N,K1), B3(N,N)
214 '
216 ' CC is for the objective function
218 ' B1, B2 and B3 are used for the computation of CP
220 ' R and C are "row" and "column" indices
222 '
224 ' Initially, set XNew = AO, the center of simplex
226 '
228 FOR C = 1 TO N: AO(C) = 1/N : XNEW(C) = AO(C) : NEXT C
230 '
232 ' T is the tolerance
234 '
236 T = .001
238 '
240 ' ALPHA is usually set equal to 1/4 ...
242 '
244 ALPHA = .25
246 '
248 ITERATION = 0
250 '
252 ' Data for constraint matrix A
254 '
256 DATA 2, -3, 1
258 '
260 FOR R = 1 TO K: FOR C = 1 TO N:READ A(R,C):NEXT C:NEXT R
262 '
264 ' Data for objective function CC
266 '
268 DATA 3, 3, -1
270 '
272 FOR C = 1 TO N : READ CC(C) : NEXT C
274 '
276 ' Set initial Value to value at center of simplex ...
278 '
280 V = 0 : FOR C=1 TO N:V = V + CC(C)*AO(C):NEXT C: VNEW = V
282 '
284 ' Now we can begin the MAIN ITERATION process ...
286 '
300 WHILE VNEW/V > T
301 '
302 PRINT USING "####";ITERATION; : FOR C=1 TO N:PRINT USING "###.####";XNEW(C); :NEXT C : PRINT USING "####.#######";VNEW/V
303 '
304 ITERATION = ITERATION + 1
305 '
306 ' Put Xnew into Xold
307 '
308 FOR C = 1 TO N : XOLD(C) = XNEW(C) : NEXT C
309 '
310 ' Construct the matrix B
311 '
312 FOR R=1 TO K:FOR C=1 TO N:B(R,C)=A(R,C)*XOLD(C) : NEXT C : NEXT R
313 FOR C = 1 TO N : B(K1,C) = 1 : NEXT C
314 '
315 ' Zero matrices to be used in computations...
316 '
317 FOR R=1 TO K1 : FOR C=1 TO K2 : B1(R,C)=0 : NEXT C : NEXT R
318 FOR R=1 TO N : FOR C=1 TO K1 : B2(R,C)=0 : NEXT C : NEXT R
319 FOR R=1 TO N : FOR C=1 TO N : B3(R,C)=0 : NEXT C : NEXT R
320 FOR C=1 TO N : CP(C) = 0 : NEXT C
321 '
322 ' Find BBT and put in B1
323 '
324 FOR R = 1 TO K1 : FOR C = 1 TO K1 : FOR I = 1 TO N:B1(R,C)=B1(R,C)+B(R,I)*B(C,I): NEXT I: NEXT C : NEXT R
325 '
326 ' Adjoin an identity matrix to BBT
327 '
328 FOR I = 1 TO K1 : B1(I,I+K1)=1 : NEXT I
329 '
330 ' Row reduce BBT|I
331 '
332 FOR R = 1 TO K1
333  IF B1(R,R) <> 0 THEN 336
334   I = R + 1
335    IF I > K1 THEN PRINT"Error: BBT is SINGULAR!": GOTO 400
336    IF B1(I,R) = 0 THEN I = I+1 : GOTO 335
```

continued

```
337    FOR C = 1 TO K2 : SWAP B1(R,C),B1(I,C) : NEXT C
338 FOR I = R+1 TO K1 : Z = B1(I,R)/B1(R,R): FOR C=1 TO K2:B1(I,C)=B1(I,C)-Z*B1(R,C): NEXT C:NEXT I
339 NEXT R
340 '
341 ' Now back substitute to finish it ...
342 '
343 FOR R = K1 TO 2 STEP -1 : FOR I = R-1 TO 1 STEP -1 : Z = B1(I,R)/B1(R,R) : FOR C = R TO K2:B1(I,C)=B1(I,C)-Z*B1(R,C): NEXT C: NEXT I
    :NEXT R
344 '
345 Remember to make diagonal entries 1's
346 '
347 FOR R=1 TO K1 : Z = B1(R,R) : FOR C = 1 TO K2 : B1(R,C) = B1(R,C)/Z : NEXT C : NEXT R
348 '
349 ' BBT Inverse is now in B1 in columns K1+1 to K2
350 '
351 ' Now multiply BBT Inverse by BT and put in B2
352 '
353 FOR R = 1 TO N : FOR C = 1 TO K1 : FOR J = 1 TO K1:B2(R,C)=B2(R,C)+B(J,R)*B1(J,C+K1):NEXT J:NEXT C : NEXT R
354 '
355 ' Take THAT and multiply by B and put in B3
356 '
357 FOR R = 1 TO N : FOR C = 1 TO N : FOR J = 1 TO K1:B3(R,C)=B3(R,C)+B2(R,J)*B(J,C):NEXT J:NEXT C : NEXT R
358 '
359 ' Find I-B3 by subtracting 1's on diagonal and changing signs
361 '
362 FOR R = 1 TO N : B3(R,R) = B3(R,R) - 1 : NEXT R
363 FOR R=1 TO N:FOR C=1 TO N:B3(R,C) = -1*B3(R,C):NEXT C:NEXT R
364 '
365 ' Multiply by D
366 '
367 FOR R=1 TO N:FOR C=1 TO N:B3(R,C)=B3(R,C)*XOLD(C):NEXT C:NEXT R
368 '
369 ' Find projection of CC and call it CP
370 '
371 FOR R=1 TO N:FOR C=1 TO N:CP(R)=CP(R)+B3(R,C)*CC(C):NEXT C:NEXT R
372 '
373 ' Find length of CP and the normalized CP
374 '
375 AA = 0
376 FOR C=1 TO N : AA = AA + CP(C)*CP(C) : NEXT C
377 AA = SQR(AA) : FOR C=1 TO N : CP(C) = CP(C)/AA : NEXT C
378 '
379 'Find a*, project back to get new X ...
380 '
381 AA = SQR(N*(N-1))/ALPHA
382 FOR C=1 TO N : XNEW(C) = (AO(C) - CP(C)/AA)*XOLD(C) : NEXT C
383 '
384 ' And remember to divide by "size" of new X to complete the projective transformation
385 ' back to the original simplex
386 '
387 AA = 0
388 FOR C=1 TO N : AA = AA + XNEW(C) : NEXT C
389 FOR C=1 TO N : XNEW(C) = XNEW(C)/AA : NEXT C
390 '
391 ' Find objective function Value at NEW point X
392 '
393 VNEW = 0
394 FOR C=1 TO N : VNEW = VNEW + CC(C)*XNEW(C) : NEXT C
395 '
396 WEND '  End of main iteration loop ...
397 '
398 PRINT:PRINT"Tolerance reached: Vnew/Vinitial = "; VNEW/V:PRINT
399 PRINT USING "####"; ITERATION; : FOR C=1 TO N:PRINT USING "###.####";XNEW(C); : NEXT C :PRINT USING "####.#######";VNEW/V
400 END
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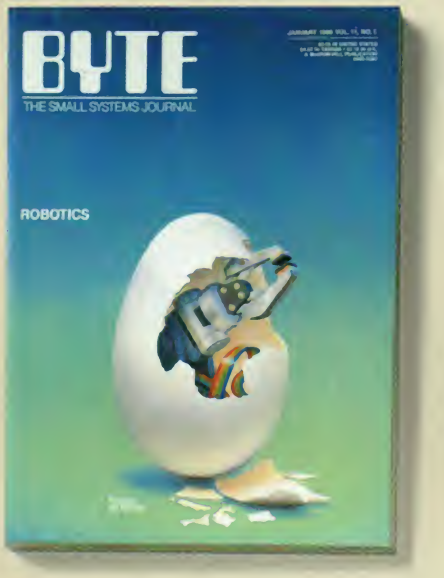

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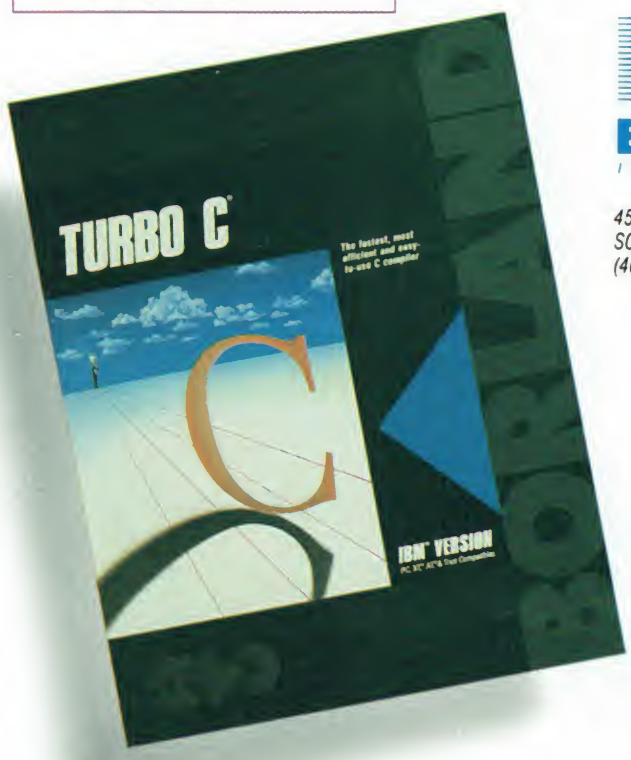

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